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# WALKER'S USEFUL HINTS ON VENTILATION.

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# USEFUL HINTS

ON

# VENTILATION;

EXPLANATORY OF ITS LEADING PRINCIPLES,
AND DESIGNED TO FACILITATE THEIR
APPLICATION TO ALL KINDS OF
BUILDINGS.

BY W. WALKER
ENGINEER.

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# VENTILATION.

AMONG the subjects connected with sanitary reform, many of which have latterly occupied a considerable share of public attention, and some notice on the part of the engineering profession, none, perhaps, deserves to occupy a more prominent place than that of ventilation. Much, indeed, has of late years been said and written on the subject; but when we consider how many publications have been either partially or wholly occupied with advocating it, it is truly lamentable to reflect how little, in this age of rapid progression, has been really *done* towards effecting an improvement in the atmosphere breathed, during the greater portion of their time, by the masses of the urban population. The greater proportion of the buildings which they inhabit, whether the steam-heated factory, the crowded workshop, or the small and close apartments of the workman's home, having been erected before the subject had been agitated, are still left, in great measure, in their primitive state of closeness and unwholesomeness—the cost of alterations being an effectual barrier to the adoption of any but temporary and partial expedients; and it is only in new buildings that much amendment can be hoped for. In such, more attention is being paid to the subject; and many churches,

banks, and public buildings, and also some few factories, bear testimony to the improved ideas of the age, and to the sanitary progress of "the land we live in." But it is much to be lamented that numerous buildings are yet constantly springing up, in which an unwise parsimony pulls more strongly in the wrong direction than the love of health and comfort does in the right—and even where liberality of expenditure has been manifested by the profuse ornamentation of ceilings and windows, it is found too late, that a small share of what has been lavished on outside display cannot be obtained for the more useful purposes of health. In such buildings, too, it is frequently found that had the subject been considered in time, and proper sanitary measures incorporated with the original plans before the erection were commenced, they could have been carried out at half the expense that is found to be necessary when the matter is taken up too late. But in the factory or the humble dwelling of the working man, seldom is any thought even now bestowed on the subject, beyond the pernicious practice of ventilating by windows, the evils of which will be hereafter pointed out. It is hoped that the tendency of the following remarks will be in favour of sanitary improvement in this respect.

Ventilation means, the changing of the air or atmosphere of buildings or apartments, by the withdrawal of that which has become vitiated or foul, and the substitution of that which is pure and fresh. This necessarily implies, entrance and exit;

entrance for the pure air, exit for the vitiated. It appears from the experiments and observations of numerous medical and other authorities, that a certain average quantity of air is spoiled or vitiated in one minute, by one person, and that a certain quantity more is rendered unfit for respiration by gas-lights, and other causes of vitiation; the sum of these may be taken as the extreme quantity of air required for every individual per minute. This, or nearly this quantity, is required in winter as well as in summer; and as its introduction in large quantities at one point would produce injurious and unpleasant drafts and currents, proper attention must be paid to its diffusion, so as to introduce it at as many points as possible, and to subdivide the currents into as many smaller currents, as the circumstances of each particular case will admit of. Moreover, however much diffused or subdivided these currents may be, their effect in cold or frosty weather will not only be cutting and unendurable in their immediate neighbourhood, but they will lower the general temperature of the apartment or building to an uncomfortable degree. Hence the necessity of warming the air to a sufficient degree *prior to its entering the apartment*. Due attention being given to these considerations, the whole art of ventilation, therefore, appears to be, the effectual withdrawal of vitiated air, and the supplying, in lieu thereof, of fresh air, in proper quantity, at a proper temperature, and in an unobjectionable manner and place, and in the skilful adaptation of the means

necessary for this end to such materials and constructive ideas as are adopted in modern buildings.

The most obvious mode of admitting air into, and discharging it from, apartments, is by leaving or making openings in the floor, or at the lower part, for its entrance, and at the upper part for its exit. We know that respired air is warm, therefore lighter than cold air; and hence that it seeks the ceiling; in the same way we know that the products of combustion of gas-lamps or burners, being hot, ascend; also that air warmed by contact with the human body has a similar ascending tendency. All these accidental sources of heat (to say nothing of intentional or artificial ones) impart an upward direction to the atmosphere of rooms; which is increased in proportion to the number of persons, lights, &c., in the room; and which is still further increased, if one or more openings be made in, or level with the floor, so as to open a communication with the external air, which being colder, presses downwards in the same manner that the internal air tends upwards; and if one or more openings be made in the ceiling, this upward tendency or pressure causes air to pass out through them, and its place is supplied by air pressed in through the openings near the floor, by the downward pressure of the colder external air; and in this way a constant current through the room will be maintained from the floor towards the ceiling, so long as the sources of heat remain in the room, and until its temperature is the same exactly as that prevailing outside the building.

This supposed case, being that of a single room, is the simplest that can occur;—and were it not for complications caused by numerous rooms in one building, and for numerous disturbing influences, both internal and external, which constantly occur in practice, ventilation would be a very simple matter, by merely keeping always in view the ascensional tendency imparted to air, in common with all fluids, from the action of heat diminishing its specific gravity. Let us now consider briefly these disturbing influences,—first, those which are from without; and next, those proceeding from within.

We have seen that the cause of motion, or the ventilating power, is derived from the difference between the internal and external temperatures. It will therefore be the greatest, and the ventilation the most perfect, in the coldest weather. Let us suppose that the external air is at 32° Fahrt., and that the room is at 62°. We shall then have a ventilating power equal to 30°, which is rather an extreme case. If we suppose the air externally to be in a state of perfect rest, the upward tendency will be, under that favourable circumstance, not very powerful—that is, the sensation at the openings will not be equal to that felt in a strong breeze; but if we suppose a gale to be blowing outside, the ventilation will either be greatly increased, or altogether counteracted, according as the openings above for exit, and below for entrance, may be favourably or unfavourably disposed or situated for

being acted upon by it. If the exit opening be turned towards the wind, or the entrance opening away from it—if the room be surrounded by trees or other buildings—or if, from any other cause, the force of the gale without be so directed upon the openings as to oppose the moderate ascensional tendency within,—in any of these cases the ventilation will be either stopped, or turned in the wrong direction.

This leads to a consideration of the defects of all methods of ventilation by windows, which are made, not for the admission of air, but of light; and which abundantly repay mankind for any unfair attempt to saddle them with more than their legitimate duty, by inflicting coughs, colds, rheumatisms, and numerous other ills that (in this climate, at least,) "flesh is heir to." Multitudinous are the devices miscalled "window-ventilators:" from the old-fashioned whirligig, spinning round in a tin-plate, to those prolific generators of ear-ache, formed of slits or perforations through the glass panes. Their name is "legion," and the family is continually increasing. In fire-proof factories, there is frequently no provision left, either for entrance or exit of air, except by making the upper part of the windows on each side to let down, like an ordinary house window, or by making the central part of each window to open and shut on pivots; either of which plans, being strictly window-ventilation, is manifestly bad, for the following reasons:—

Not only is the external air subject to great varia-

tions in the velocity of its motion, being sometimes perfectly still, at others having only the gentle movement of a zephyr, and often rushing with the violence of a gale, at a speed of thirty or forty miles per hour; but variations also take place in the point of the compass from which it blows. Hence, its force is directed, sometimes against one side of a building, sometimes against the very opposite side; frequently causing those openings in the windows, which were intended for egress of air, to have the contrary effect of admitting it, converting them into openings of ingress, and reversing the action desired. In such case, the air, entering by the windows on that side on which the wind operates, cannot be warmed previously to entering the room; and if the building be a factory, heated to a temperature of 60° or 70°, and the external temperature be at the freezing point or below it, the piercing effect of a downward current of such cold air in a hot room is so dangerous and unendurable, that the inmates will prefer closing the windows and doing without ventilation; choosing to breathe vitiated air, rather than be subjected to such dangerous chilling influences. The necessity of warming the air before it enters the room, has been most clearly exemplified in certain flax-mills, in which it was considered that most judicious measures had been adopted, by making openings for fresh air, through the side-walls under each of the windows. These mills were heated in the usual manner, by steam-pipes suspended from the ceiling along the centre of the room, near the top. Openings were

also made for egress of vitiated air over the windows. This plan performed very well during the whole summer, but as soon as frosty weather set in, it became impossible to keep the ventilation in action, owing to the determination of the workpeople (chiefly females), who seized every opportunity of stuffing up the openings with tow and flax, in order to put a stop to the piercing draft and coldness which they experienced about the feet. There was abundance of heat generated, but it was all carried off through the upper openings, without influencing at all the lower part of the room. Had the air been admitted in a warmed state, the ventilation would not have been objectionable, and the temperature would have been more equal from the ceiling to the floor.

Window ventilation is also frequently and most injudiciously practised in churches and places of worship, as well as in large rooms where public meetings are held. In galleried buildings, it is most especially dangerous; those openings in the upper parts of the windows, which were intended for egress, frequently acting, sometimes on one side of the building, sometimes on the other, as ingress-openings, directing strong currents of cold air into the hottest parts of the building directly upon the heads of persons seated uncovered in the gallery. There is little doubt but that many coughs, colds, toothaches, &c., arise from this cause alone; especially coughs, which, in severe weather, prevail to such an extent, afflict so large a proportion of every congregation, and are so incessant during the period of divine service, that a

person unaccustomed to it might fairly imagine that the minister or speaker had incurred the displeasure of the audience, and that the latter were engaged in a resolute endeavour to "cough him down."

In private dwellings, too, the effects of the want of a proper provision for the admission of previously warmed fresh air into the various rooms, are severely felt and clearly demonstrated by the elevated shoulders and crouching attitudes of, perhaps, the whole family, closely packed together round the cheerful fire—their faces almost scorched by its radiations, while their backs are chilled and rendered comfortless by the piercing currents which insinuate themselves through every chink and crevice of the windows and door. In such rooms, however, the defect is not one of egress, but of ingress, which takes place, for want of a proper provision for admission of warmed air, by the entrance of cold air through whatever apertures chance may permit; and as the readiest chance is through the crevices round the window-frames, it may properly be noticed while speaking of the evils of ventilation by means of windows, or of openings made in them. Vertical openings in upright walls, or in the sides of apartments, if they communicate immediately with the external atmosphere, are objectionable from the same cause: they are liable to be acted on by the prevailing wind, which, blowing sometimes in one direction, sometimes in another, and sometimes not at all, renders their action uncertain and not to be depended on. Generally speaking, the exterior terminations of all

ventilating-openings, whether for ingress or egress, should be in a horizontal, rather than in a vertical plane.

Having noticed the principal external causes which influence the operation of ventilating appliances, and frequently render them nugatory, it remains to speak of such as are internal; that is, which proceed from within the building itself. The most frequent of these is, multiplicity of rooms; the proper ventilating current of one, acting sometimes in a direction contrary to, and overpowering, those of another. The best way to obviate this is, to treat all the rooms as parts of a whole, and make them all subservient to one general scheme or system. If two rooms on the same level be separately ventilated, and the means employed in one be more powerful than those used in the other, the stronger will overcome the weaker; and instead of drawing its fresh air through its own intended channels, will probably draw it, or some of it, from the other rooms; the intended action of which will therefore be reversed, and an inward action will be established through its egress-openings. If the various passages or air-channels be not properly proportioned to each other, and to the sizes of their respective rooms, the same effect will also occur. It will likewise occur if there be more than one ventilating flue to one room, unless great care be taken to equalize their upward action. The stronger will overcome the weaker, and neutralize or reverse its action. A room having a large fire burning in it, as a kitchen,

for instance, will reverse the proper ventilating currents in several small rooms communicating with it, drawing air from them to supply its combustion; the proper remedy for which is, to furnish it with an independent fresh air supply of its own. A tall narrow staircase will sometimes destroy the intended course of the air-currents for ventilating rooms opening into it; acting on them, when their doors are open, as a shaft or chimney, by drawing air out of them; not only counteracting their ventilation, but causing their chimneys to smoke. All these, and many other, internal impediments to ventilation may be overcome, by acting on the general principle of giving to each room its separate fresh-air supply, and vitiated-air discharge; making all the fresh-air flues communicate with an air-chamber, supplied from the exterior, in which are to be placed adequate means for warming the air prior to its distribution through the several flues into the apartments; and conducting all the vitiated air-flues into a main trunk or shaft, discharging its contents above the roof—taking care, at the same time, to preserve a proper proportion between the sizes of the rooms, and of their respective ingress and egress flues and openings; and also between the aggregate sectional dimensions of the flues, and those of the main ingress and egress trunks with which they communicate.

In buildings not yet constructed, these principles may be easily carried out at moderate cost, and without any serious inconvenience as affects the purposes of the building, whether it be contem-

plated to make it a house for worship, for business, for public meetings, for purposes of manufacture, or of domestic comfort. The skilful practitioner, understanding the proper sizes of which the air-flues should be constructed, and the principles which will ensure the success of their performance, will find little difficulty, if consulted before the plans are finally determined upon. But, as before stated, his difficulties are infinitely augmented, if, as is too generally the case, he be not applied to till the building is erected, and the available funds nearly all expended; if the purposes of health and comfort be made secondary to outside show; and if proper appliances for those purposes be only looked on as needless or luxurious adjuncts, which may or may not be adopted. Ventilation has been too much looked on as a mere matter of applying tin pipes, breaking out a hole here, and putting in an iron grating there,—as a matter which need not be thought of till found necessary,—and as a thing which could be efficiently done at any time, irrespective of any difficulties of internal construction or external circumstances. Some persons have entertained very sanguine expectations from the copious use of plates of perforated zinc, (very useful when used with judgment,) as though the whole art of ventilation lay in their adaptation, or as though the fixing of them in any imaginable position could change the direction of a current of air, overcome the force of powerful winds, or impart motion, when needed, to a stagnant atmosphere. But it is

highly necessary, if the evil effects deplored by medical authorities as the results of imperfect ventilation do indeed proceed from that cause, that improved plans for remedying the defect be incorporated with the construction of every new building; and there is no reason why they should not, down to the humblest class of dwellings, not excepting even the workman's cottage, when it can be done originally at a very small outlay.

It is a most singular fact, and one worthy the notice and inquiry of the moral philosopher, that while our gentlemen-farmers and rich manufacturers spend considerable sums with the very laudable object of improving and ventilating their stables and cow-houses to promote the health of beasts, so many of them still suffer the dwellings of men, their peasantry and work-people, to remain unpurified and uncared for. It has fallen to the lot of the writer, in numerous instances, to remark this singular phenomenon;—that in large establishments, where no cost is spared to keep cattle in healthy condition, in the belief that it is not money thrown away, and that it will enable them to live longer, and to perform their work better; yet, on the health and strength of numbers of men, women, and children employed in the same establishments, no thought is bestowed—no money expended. In one very extensive set of domestic offices attached to the mansion of a trader of great wealth, whose hobby it was to maintain a good stud of horses, a neat range of stone buildings, with costly provision

for drainage, cleanliness, lighting, and ventilation, was appropriated to the sleek and well-fed animals, with a separate and artificially-warmed enclosure set apart as an hospital for cases of sickness. Within 300 yards of this building was the *den* appropriated to the gardener—a mere shed, in the rear of a hot-house, consisting of but one apartment for the daily use, and a mere closet for the nightly occupation, of himself, his wife, and family of four children. The door was wide open, for the double purpose of ventilation and prevention of smoke from the chimney. What must have been that man's thoughts on leaving his own dark and unwholesome stye, and surveying the comparative palace provided for the horses? It were unreasonable to expect that either his mind should remain in a contented, or his body in a healthy condition. The same perverted feeling prevails in very many cases, where the health of cows and cattle is much more sedulously cultivated than that of the less fortunate human beings who have the charge of them. If the voice of philanthropy be not powerful enough to change such a state of things, that at least, of interest and selfishness may; in which case, the question may be propounded, whether the bone and sinew of a man will not repay a sanitary outlay as profitably as those of a horse: and though the former is not, like the latter, a saleable and transferable property, yet a healthy population in the vicinity of a farm or factory will, it is believed, by the better performance

of labour and the immunity from numerous charitable contributions which accompanies it, repay any moderate sum expended in its promotion.

These considerations suggest that a small investment of money in improvements for the promotion of health in the dwellings of the working classes, especially in those not yet constructed, would not prove unremunerative, as they would tend directly and rapidly to a reduction of poors'-rates, a diminution of calls on the charity of employers in time of sickness and disability, and an increase in the effective strength which could be hired for a given amount of wages. This argument addresses itself especially to manufacturers, who are generally the landlords of those in their employment, for whose use and occupation they build long ranges of cottages in the vicinity of their mills and factories; their contiguity to the steam-engine furnishes a ready means of supplying them, at small expense, with abundant quantities of fresh, warmed air. Below the ground level of a row of cottages, a horizontal trunk or shaft for fresh air should be constructed; made impervious to wet, either by drainage or by water-tight cement, and its ends protected from the intrusion of small animals and vermin by wire gauze or perforated zinc. At that end of this shaft which is nearest to the engine, a chamber should be formed, filled with pipes or other heating-surfaces, with cocks to regulate their temperature; through which chamber air should be propelled by a fan, screw, air-pump, or other forcing

instrument, worked by the engine. From the top of this horizontal trunk or shaft, vertical shafts should be carried straight up, one through each cottage, divided horizontally at the ceiling of the lower rooms into two parts—the lower part communicating with the spaces between the joists by means of openings left in its sides between the ceilings and floors. By using these spaces as horizontal air-flues, air may be easily conveyed under the floors to that side of the room which is opposite to the fire-place, where it may be allowed to enter the room through an opening made either in the floor or skirting, (the latter is preferable,) at which a sliding plate should be fixed, to regulate its quantity. The upper part of the shaft should have openings in its sides communicating with all the rooms, for vitiated air to escape at the side of the room opposite to that by which it enters. By these means a complete system of warmth and ventilation would be established through a long row of cottages; and if the plans were laid before commencing building, it could be executed at very small expense. The shafts and air-flues could be arranged by a judicious and experienced ventilator in such a way as to require scarcely any more materials than are required by existing plans of construction,—the main horizontal air-trunk and hot-chamber being the only additional items of builder's work. The power requisite for driving the air would be so little as scarcely to be felt by a large engine; and the heat in cold weather is obtainable, without cost,

from the waste steam, by arrangements which have already been most successfully carried out.

It is not proposed here to lay down a complete system of ventilation for cottage buildings in general; but a careful consideration of what has been stated will lead to the general principles to be adopted, which must be varied in their application to particular cases, according to the nature of each building and the purposes to which it is to be applied; and there can be little doubt, looking at the moderate expense of sanitary measures as a pecuniary investment, but that they would prove to be a profitable outlay to the building manufacturer, as well in the cottage as in the mill or factory.

Having shown how cottages and small dwellings contiguous to a factory may be planned so as to be efficiently warmed and ventilated at moderate cost by the steam-engine, it remains to explain the mode of conferring similar benefits in the factory itself; a subject which will assume, at least, an equal importance, when it is considered how large a proportion of time is passed there, both by the employers, the employed, and those holding intermediate stations. The causes of vitiation being here in much greater force, from the large amount of gas consumed, the greater number of persons congregated in a given space, the oil used in the machinery, dust evolved from the materials operated on, and other sources, a more copious supply of fresh air, and more powerful means of warming it, become

necessary. Such buildings have generally been constructed simply with a view to warming them from the top of each floor, irrespective of any ventilation, except that derived from the casual and uncertain operation of windows—the radical errors of which plan have been already pointed out. The *fire-proof* construction now so frequently adopted in factories, and the complete isolation of the various floors from each other, requisite to the perfect fulfilment of fire-proof conditions, materially increase the cost and difficulty of applying proper ventilating arrangements, unless taken in hand prior to their erection; but if *then duly considered*, this mode of construction rather facilitates their application than otherwise—the spaces between the spandrils of the brick arches which form the ceilings and the floors over them, and also the interiors of the hollow iron columns, forming valuable channels for egress of vitiated air; at the same time that the numerous piers between the windows—their thickness being increased to rather more than that usually observed, for the sake of strength—afford a valuable means of conveying fresh air by vertical flues within them to the various stories. The size and proper distribution of these channels and flues must of course be determined by a person of judgment and experience, it being only intended here to convey general ideas. The vertical ingress-flues in the piers should all be furnished with valves or regulators in the rooms, at the ingress-openings, and their lower ends should be connected with main horizontal air-trunks, one

on each side, running under the ground-floor the whole length of the building (great care being taken to have them constructed of a proper size.) These main trunks should be connected with a blowing or forcing apparatus, worked by the steam-engine, and with a hot chamber fitted with a proper quantity of heating-surface, heated by the waste steam, in the same manner as recommended for the workmen's dwellings.

This method of ventilating is one which unquestionably ought to be adopted in all factories and habitations connected with them. There can be no doubt of its proper performance, nor of its beneficial influence on the health and habits of those coming constantly within the sphere of it, as well as on the amount of labour performed by them, which could not fail to re-act beneficially to the interests of the employer, and repay him (indirectly, and imperceptibly, perhaps, but no less surely,) for his outlay. These views have already been acted on by some few spirited manufacturers, on a large scale, and their example is being slowly followed by others: but when we cast our eyes over the vast manufacturing establishments of this country, and mark the difference between the appearance of their inmates, whose lives are spent in rooms where change of air is left to chance, and that of the agricultural population, whose out-door employments subject them to the invigorating influence of every passing breeze, the conclusion is irresistible, that what little has been done towards assimilating their conditions,

and equalizing their chances of health, vigour, and longevity, is like a drop in the sea; and that there is indeed a wide field open to the exertions of the philanthropist, and to the skill of the sanitary engineer.

The method of ventilation by power is, unquestionably, the best that can be adopted, wherever there exists an engine for other purposes, or where the amount of ventilating duty to be performed is sufficient to justify the employment of a small one for that express purpose. Its effects are sure and infallible—any amount of air may be driven by it with certainty in any desired direction, and warmed, when the weather requires it, to any degree requisite for human comfort. The moderate cost at which steam-engines can now be supplied, is a material consideration in favour of ventilating by power. In some recent cases, a very simple form of direct-acting engine has been applied to this special object with success and advantage. Apparatus have also been invented, not only for simplifying the prime mover, but also for diminishing the attendance usually required by warming and ventilating contrivances; so that the means to be adopted are now so devoid of complexity, and the trouble of using them so much diminished, that it is hoped that ventilation by power will become much more generally used than has hitherto been thought of, even in buildings where steam-engines are not required for other purposes; the certainty of its action being such, and its effects so completely and instantane-

ously controllable, as to entitle it to a decided preference wherever it can be applied. The reasons for this preference will have the greater weight when we consider, that owing to the difficulties which will sometimes unavoidably oppose themselves to the construction in buildings of flues and air-channels of size sufficient to convey the requisite quantities of air for crowded assemblies, they must occasionally be of a size which will prove to be too small for the purpose, unless their activity be increased, and the velocity of the air passed through them be accelerated, by the impulse of some mechanical propeller, of power adequate to overcome the greater resistance caused by such increased velocity.

To no class of buildings will this remark apply with greater force than theatres, assembly and ball-rooms, and lecture-rooms, where very great numbers of persons are frequently packed together, tier over tier, in the smallest possible space; their number at the same time being subject to great and sudden increase and diminution, and demanding, therefore, highly controllable ventilating agencies, so as to be quickly adapted, *without change of temperature*, to the greater or less number suddenly present at any given time. In theatres, particularly, these practical difficulties have been experienced by the writer to be rendered much more formidable, from the extreme value of space not permitting a single seat to be *sacrificed* (?) to purity of atmosphere. The expenses of large theatres are so great, and the extravagant demands of the principal performers

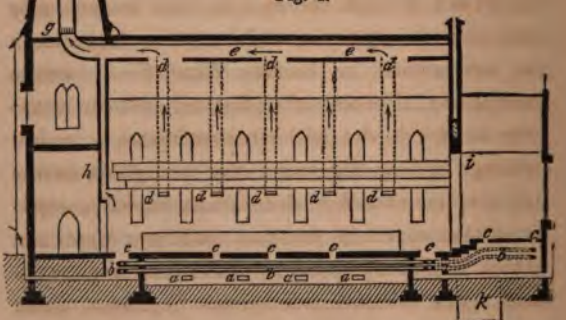
or "stars" so serious, that, in the provinces especially, their appearances are only occasional; and it therefore becomes necessary, in order to make those comparatively rare occasions pay the current expenses of the whole year, that sitting or standing room should be provided in every space within view of the performance, into which a human being can possibly be crammed. This increases the necessity for ventilation, at the same time that it diminishes the facilities for obtaining it; and as space cannot be spared for thickening walls, so as to run up air-flues within them, or otherwise for constructing the desired air-channels, they are of necessity small, few, and far between; and these deficiencies can alone be compensated by forcing air through them at a higher velocity than that which would be caused spontaneously by the elevated temperature of the house. Again, at the conclusion of a favourite performance, and before the commencement of the after-piece, the house is frequently, and almost entirely, deserted. Hence the advantage of using power in such buildings, as it furnishes the only means by which inadequate channels can be made to perform double duty on special occasions, or by which their activity can be instantly lowered on a sudden cessation of the requirement.

But, however useful steam agency, as applied to ventilating purposes, may be in factories or buildings connected with them, and in theatres or other places liable to great and sudden influx or efflux of persons; and well as it has been found to answer in

its application to other buildings, such as club-houses, banks, collegiate institutions, and hospitals, in which manifest advantages have been derived from its employment; there will still be great numbers and many classes of edifices in which it would be, from various causes, inadmissible. Churches, chapels, and houses for worship, may be enumerated under this head,—the numbers contained within their walls being, on the whole, tolerably constant, and not liable to very sudden fluctuations; but especially from the circumstance that they are seldom used more than two days in the week, with intervals of two or three days between; and when used it is only for two hours consecutively, with intervals of two or three hours between. With such proper quantity and sizes of ingress and egress flues as can readily be obtained in the thick walls and piers of such edifices, (if planned prior to their construction,) this short period of occupation will not permit their atmosphere to become very highly charged with impurities, while the intervals between the services will be found sufficient for an entire change of the whole atmosphere left in them at the close of each service, without resorting to mechanical means. In churches with lofty open roofs, of the mediæval or early-English construction, without galleries, the total cubic space bears so large a proportion to that portion of it occupied at the floor level by the congregation, that scarcely any injurious vitiation of the entire atmospheric contents can take place during the short period of occupation, provided

moderate preparations have been made for ingress and egress. Hence, very sudden and powerful ventilation is scarcely required in such churches, and the purification of their atmosphere may safely be left to the spontaneous action of those preparations; but on special occasions, and in hot weather, the action of the fresh-air flues may be accelerated by the exhausting power of a shaft or trunk of adequate size running up within the tower or steeple, its upper end discharging into the external air, while its lower end communicates with the interior by openings in or near the roof; and this shaft may be made, in very hot weather, to perform two or three times its usual duty, by rarefaction produced at its lower end by a large number of gas burners fixed there in tolerably

Fig. 4.




close proximity with each other, and supplied with gas from the mains which furnish light to the

whole building. These ideas have been successfully carried out in numerous instances and in large buildings. The whole process recommended for such a building will be better understood by a reference to the upper portion of figure 4, which represents a section of a church ventilated in this manner. *a a* are openings all round the church for admission of fresh air; *b b* hot-water pipes, over which it is made to pass on its way to the gratings *c c; d d* are openings, by which the vitiated air enters a horizontal trunk *e*, from the end of which rises the shaft *f*, with a collection *g*, of gas-jets in the bottom of it; *h i* is the gallery-line, and *k* an excavated room for the boiler, the floor of which should be five feet below the floor-line of the church.

By simply turning the cock in the gas pipe which supplies the jets, the rarefaction in the shaft, and consequently the velocity and quantity of the air passed through the church, may be controlled with tolerable accuracy, and instantly proportioned to any greater or smaller number of persons assembled. The cost of piping and cock for bringing the gas to the jets has been found to be but trifling; and as they need only be lighted during the time the church is occupied for worship, which is seldom of longer duration than two hours and a-half, the consumption of gas is not very great, and amply compensated by the beneficial result obtained.

In such churches, chapels, and meeting-houses,

however, as have flat roofs and broad galleries running sometimes all round them, the vitiation of their atmosphere which takes place during the period of occupation, is much more rapid than in the open-roof class of churches just alluded to, owing to their cubic contents bearing a much smaller proportion to the numbers which may be congregated in them. In such buildings, seeing that mechanical ventilation by steam-power cannot, for obvious reasons, be made use of in them, every other means must be adopted that their construction will admit of, for the spontaneous changing of the air fully as fast as it can become contaminated; and such spontaneous and copious action must be assisted and increased, when practicable, by the aforesaid means of a shaft highly rarefied by gas. Many very crowded meeting-houses have no spire or turret within which a shaft may be constructed; but this difficulty is fast vanishing away under the rapid revival of architectural taste, and a desire which seems to have taken possession of numerous religious bodies to assimilate their devotional edifices as closely as may be to those external forms and modes of building which were adopted for ecclesiastical purposes by the promoters of the Catholic religion in the middle ages. But where a spire, tower, or turret, is not intended to be introduced for architectural display, may not its utility, in the promotion of health and comfort, plead for its introduction into the design? Before these "Hints" are brought to a conclusion, occasion will be taken

to point out how materially such an appendage, in connection with proper contrivance for supplying fresh air, would not only promote the effective ventilation of many buildings, but also render the nuisance of smoky chimneys a thing unknown.

The means most proper to be adopted for the plentiful supply of fresh air in the low-roofed, galleried, and crowded meeting-house, will be found to consist in abundance of fresh-air openings all round under the windows, communicating by brick flues with the lower part of the spaces under the aisles and seats in which the hot-water pipes that are to warm the air should be fixed. Fresh-air flues should be constructed in all the piers between the windows, running as high as the gallery to supply it with fresh warmed air. A vitiated air-flue should also commence in each pier under the gallery (in order to give free egress to that which would otherwise be intercepted and detained under the gallery), and pass up into a horizontal trunk, running over the roof, along each side, into the foot of the upright shaft below the gas-jets, as before explained. Openings should also be left in the roof, communicating with these horizontal trunks, to carry off the bad and heated air over the galleries. Hot water pipes should be conveyed along the side-walls, under the floor, so as to warm the air that passes up within the piers into the gallery.

The leading points to be observed in such a case are delineated in the lower part of Figure 4, below the line *h i*.

A much larger provision should be made for supplying fresh air to such a house for worship, or other galleried building, than in one which has no gallery, and which possesses the advantage of an open roof; and those who would object to the copious measures here recommended, as unnecessary, should well consider the following facts and calculations. A chapel or meeting-house with large galleries nearly all round, capable of accommodating on special occasions 2,000 persons, is frequently made about 75 feet square, and 25 feet average height, giving a total cubic content of rather more than 140,000 feet. Now the authorities, from Tredgold to Reid, who have written on the subject of the quantity of fresh air required per minute by each individual, to replace that which such individual has rendered unfit for respiration, vary in their conclusions from $3\frac{1}{2}$ to 10 cubic feet; and if seven cubic feet be assumed to be the proper quantity, an allowance near the average of their scientific opinions will be given. The total quantity required therefore on this low standard in such a building, to maintain its atmosphere in a state of purity when filled, will be ($2{,}000 \times 7 =$) 14,000 cubic feet every minute, and a like quantity of vitiated air must be carried off in the same time. The atmosphere of the building will therefore require to be completely changed or renewed ($140{,}000 \div 14{,}000 = 10$) *once in every ten minutes.* Let it now be supposed that the unusual provision of 16 openings has been made all round the building, for fresh

air, each opening measuring 18 inches by 6 inches. Deducting one-third of the area for impediment caused by gratings, will allow to each opening a clear area of half a superficial foot, and the aggregate area of all the openings will be eight feet. Now, to supply the required quantity of air (14,000 cubic feet) in the given time (one minute) through those openings, the air must pass through them all at the velocity of (14,000 ÷ 8 =) 1,750 feet per minute, or more than twenty miles per hour; which it will not do, especially on a calm day in hot weather, *when ventilation is most needed*, without the aid of some powerful stimulus; and if such artificial impulse be wanting, those openings will, under the circumstances, be quite insufficient to prevent the rapid deterioration of the atmosphere within, and ought therefore to be considerably enlarged. The bad effects of the usual way of obtaining a partial supply of air in such a case by opening the windows, have been already commented on.

Take another example from a large gothic church, with galleries, and lofty side aisles and nave, in the neighbourhood where this is written; measuring 80 feet by 65 feet, with a roof approaching to flatness, about 30 feet in average height. This church has often contained 1,800 persons; its cubic contents being 156,000 feet, and the requirement of air, allowing as before seven feet per minute to each person, (1,800 × 7 =) 12,600 feet. The time in which the whole atmosphere of this church would, when containing its full complement of persons, re-

quire to be changed, is (156,000÷12,600 =) $12\frac{1}{2}$ minutes; and large openings will obviously be required to pass the quantity in the time.

These figures will suffice to show the necessity for a very much larger provision for ventilation than has been customary in buildings containing galleries; in which the cubic contents bear a small proportion to the numbers assembled.

The proper warming of the air is an important part of the ventilation of churches and chapels, and requires an adaptation of apparatus to that end, more in accordance with natural laws than has generally obtained in practice. A passing allusion to the tendency of heated air to ascend in a vertical column from the source of heat, will suffice to demonstrate the fallacy of expecting a church, or any other large building consisting of only one spacious apartment, to have a good distribution of warmth effected over its whole area, from one stove fixed, as has frequently been done, at or under one end of it. If the air be allowed to escape at once from such stove, it will ascend straight up towards the roof, and the heat be carried off at once through the egress aperture, without affecting the body of the church at all; or, if it be attempted to convey it to the other end by flues laid under the floor, with openings at intervals for escape of the heat, one of the following results will occur; either contrary currents will prevent any heat at all from ascending, or it will all escape at the first openings, and be expended long before it reaches the end. The stove

or heating apparatus is usually fixed at the east end, under the chancel; in which case, the heated air is required to overcome all impediment caused by friction within the flues, and to travel in a westerly *horizontal* direction, (in opposition to its *vertical* tendency) for a distance of sometimes 80 or 100 feet. The most formidable impediment to the success of such an arrangement lies in the fact, that the prevailing winds in this country blow in an exactly contrary direction, from west to east; and their force has frequently been known to reverse completely the intended movement, causing air to descend from the church through the stove, and issue heated into the exterior. The most suitable and successful arrangement for churches, is to conduct hotwater pipes all along the church from end to end, under the floor, with gratings over them for escape of warmed air; the air-flues being so arranged as to cause the fresh air to impinge on them before it enters the church through the gratings. This plan, carried out with a due regard to a *sufficiency of heating surface*, (the want of which is a constant source of error) provides a source of heat in every portion of the length of the building; and causes the vertically ascending tendency of the warmed air to act alike in every part of the building, whereby it ensures the *general distribution* of the heat.

A church may certainly be warmed sufficiently by a stove, (and it has frequently been done,) by closing all egress openings, and heating the same air over and over again. The same total prevention

of all change of air will also cause a very insufficient hotwater apparatus, with the aid of the animal heat given off by the breath and bodies of the congregation, to produce sufficient warmth. But it is obviously and radically wrong, inasmuch as it is *warmth without ventilation*; and, if in such case the quantity of air proper for health be admitted, it will prove to be *ventilation without warmth*.

Before quitting the subject of churches, a few remarks may be made on a very frequent cause of the failure of apparatus for heating them, arising from insufficient draft in the chimney. This difficulty has given the writer of these hints much trouble, and is one which prevails much more frequently in early-English churches than in those of any other architectural style. It arises from the circumstance, that the place intended for the stove, boiler, or other source of heat, is usually in such churches constructed at the east end, under the vestry, which is generally a low building, with a short chimney for the vestry fire-place—a second chimney being often carried up in the same stack for heating the church. The lofty ridge of the roof of the nave, being considerably higher than the top of this short chimney, causes eddies and currents to prevail above the vestry-roof highly prejudicial to the draft, from whatever point the wind may happen to blow. In all cases where circumstances render it most convenient to place the chimney at the east end, a proper draft being essential to the success of any mode of heating,

a flue ought to be left originally in the end wall of the nave, terminating a little above the apex of the ridge. (See figure 4.) This has been objected to by many, and so have numerous other useful ideas connected with our main subject, as interfering with architectural propriety; to which it may be answered, that if the external forms adopted for churches in by-gone ages cannot be adapted to the artificial necessities of the present day, more suitable forms should be chosen or invented: but that is hardly necessary as regards the point in question, since the construction of a suitable stove-room under the tower or spire, (the chimney running up within it,) and the adoption of a heating-apparatus in which coke can be used as fuel, so as to cause no disfigurement at the top by smoke, meets all the difficulties of the case.

The management of the warming of a church being a matter frequently entrusted to a sexton or verger charged with other duties, which necessitate his making a clean appearance, and demand his exclusive attention during the service, it is a matter of some importance where hot-water apparatus are used, to adopt such form of boiler as will require the smallest possible attention. The kind shown in figure 3 in the section on the front sheet, will be found to fulfil this requirement; many large churches having been kept by it at a uniform temperature with only three attendances in twenty-four hours. This sort of boiler will be found very desirable in many other buildings besides churches,

They are to be filled to the top with coke broken into small pieces, which falls on the fire as required. A very useful kind of Arnott stove has been largely adopted on the same principle.

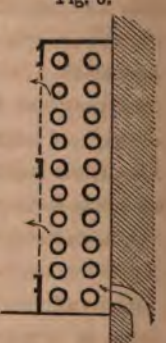
The same general principle that has been laid down for the distribution of fresh warm air into the various rooms of a range of cottages, will suffice for larger dwellings, whether connected together or detached; with this exception, that steam power cannot in such buildings be obtained, and the motive power which is to cause the air to travel in the right direction, must be sought for in the judicious arrangement of flues and channels, so as to ensure their operating in such direction, assisted in cold weather by the rarefying power of the heating-apparatus and fire-places causing an upward movement. It will be found most desirable, to provide a large fresh-air flue and hot-chamber in the cellar storey, from which flues, of adequate dimensions, should be led into every room, opening into it at the side opposite to the fire-place. A separate flue should be led to the staircase; and should the house have been built without having had the benefit of a previously-planned arrangement, the flue carrying heat into the staircase, will in many cases greatly compensate for the want of those leading to the rooms, by warming the principal trunk, or as it were the main artery of the house, from which all the passages and rooms derive their supply of air: thus modifying those cold drafts through the doors, which are the cause of so much illness and discom-

fort, and converting them into warm drafts, which will prevent their injurious effects. The most proper place for the mouth or discharging orifice of such staircase flue will be in the floor or skirting of the hall or vestibule, as near as may be behind the entrance door; so that any air finding its way through it into the hall, may become mixed immediately with the warmed air, and aid its diffusion backwards into the house. For all descriptions of dwellings, the best kinds of heating-apparatus to be fixed in the hot-chamber will be found to be, some of the numerous kinds of hot-water apparatus; a great variety of which, and of various forms, have been invented, suitable to the varying situations and local circumstances to be met with in practice: their diversity consisting chiefly in the form of the boiler and nature of the heating-surface; and also in the pressures at which they may be respectively worked. The hot water method of heating is the most suitable for domestic uses, chiefly from the simplicity of its principle and the facility of its management diminishing the chances of household servants damaging the apparatus through ignorance or ill-usage, and at the same time reducing the needful attendance to a minimum; in both which respects such great improvements have been made of late years, as to leave little more to be desired on that head.

Coils of hot water pipe, or steam pipe, may be fixed in the hot chamber before alluded to, for warming the air of dwellings, the fresh air being

introduced at its lower part, and when warmed carried off at its upper part, where the warm-air flues should commence. In some cases the hot chamber may be dispensed with, and coils or stacks of pipe may be fixed in each room over the mouths of the fresh-air flues, concealed by ornamented open-work cases. This arrangement has been adopted at the North-Western Railway station, in Liverpool, (omitting the fresh-air flues, the offices being sufficiently ventilated by the frequent opening of the doors,) and in numerous other places, with great advantage. It is a revival of the principle recommended 34 years ago by the Marquis de Chabannes, who called it his "water-calorifère;" but in his day, its introduction must have been materially impeded by the more clumsy nature and imperfections of workmanship, which had not then arrived at that compactness, neatness, and lowness of price, which it has since attained. The same idea was applied about the year 1830, by Bramah, but in a much more elaborate and costly manner than would suit the economical notions of the present day, in several hospitals in and about London; and it has been extensively used since that time in large buildings. The simplest and best arrangement, probably, on which *pipes* can be used, is that above alluded to, as in use at Liverpool and many

Fig. 5.



other places, and consists of two-inch pipes, arranged one above another in a double row, with a case of open-work in front, as shown in figure 5. A case of this kind, six feet long, one foot wide, and three and a half feet high, would contain about sixty feet of heating surface.

But the bulk occupied by the most compact arrangements of pipes, and the cost of ornamental coverings to conceal their unsightly appearance, render their application within the apartment difficult in numerous instances. In such cases, the heating surfaces may be fixed in a hot chamber in the basement, through which the air should be made to pass on its way to the rooms as before described. For this purpose, more compact forms than pipes are desirable, in order to reduce the space occupied. The simplest of these forms consists of flat hollow plates of iron, set up on edge parallel to each other, having a thin space within them of one inch wide for the reception of the vehicle of heat, and fixed at intervals of one inch and a half apart. The number must be determined by the extent of heating surface required, and any number of them may be connected together by a horizontal pipe running along the top, conveying steam or hot water to each plate, and another along the bottom, connected by a branch with each, for removing the water which has parted with its heat. The quantity of heating surface obtainable in this form in a given space, compared with pipes, is nearly as 3 to 2, or half as much again. This form

of heating surface has long been used for manufacturing purposes, in which it is applied as steam chests for the drying of goods passed by machinery over the flat surfaces. Its first application on record to the purpose of warming air, appears to have been to several public buildings, about forty years since, by a Mr. Deacon; but the clumsiness of the best modes of construction practised at that period seems to have retarded its progress. Figure 6 shows this arrangement both in plan and in section.

Fig. 6.

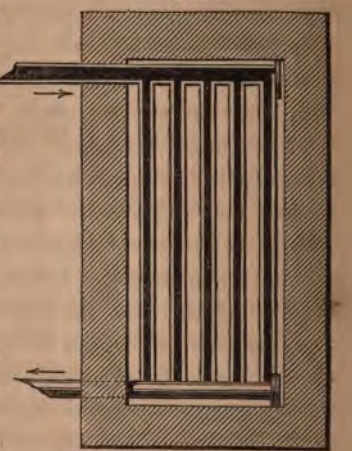
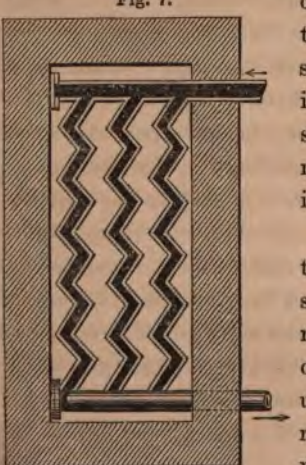


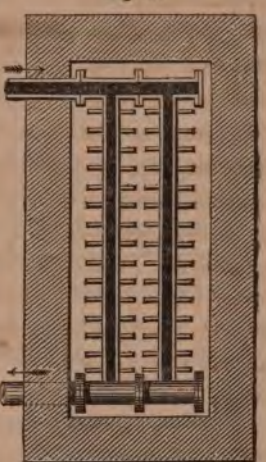
Fig. 7.



A modification of this form of heating surface, having a corrugated or zig-zag outline, has been often used; but as the corrugations cause each plate to occupy a

greater width, there is no space saved nor other advantage gained, by this alteration in the form of surface; see figure 7, which represents this arrangement in plan.

Fig. 8.



A better arrangement than the last has been used, similar to that shown in figure 6, but having thin parallel projections cast on the outsides of the plates, which increase the heating surface obtainable in a given space, in the proportion of four to two, or twice as much, as compared with pipes. This is shewn in plan, in fiigure 8.

Mr. Haden has patented a sharply corrugated form which he gives to these projections; see side view, figure 9. This is intended to bring the air more intimately into contact with the hot surfaces, by passing it up through winding channels; and also, by the obstructions and hindrances caused by the angles projecting over the passages, to cause fresh particles of air continually to impinge on the surface. There does not appear, however, to be much gained practically by compelling the air to pursue this sinuous course. What is gained in *temperature* will be lost in *time*.

It has been objected to these methods of increasing heating-surfaces by projections, that there will be a diminution of efficiency from the ends of the projections not being in such close contact with the steam, water, or other vehicle of heat that may be employed, as the sides of the plates; but within proper and moderate limits as to the length of the projections, this objection has not been found to hold good in practice; which will be more obvious when we consider that iron is one of the best conductors of heat, while air is a very slow absorbent; and consequently that for some limited distance heat will travel through the metal more rapidly than the air can take it up, unless blown through the hot chamber with great rapidity.

Fig. 9.

The same mode of gaining increased heating-surface by projecting ribs, has been extensively practised in cast-iron boilers for hot-water apparatus. But this application of it has been found liable to some objection, the draft being sometimes impeded by soot collecting in the interstices between the ribs. Boilers with external ribs have been cast, of a form which obviates this inconvenience; but cast-iron boilers, of any shape, are very inferior to

those of wrought-iron, from their greater thickness and liability to crack if cold water be allowed to pass into them when highly heated, which will sometimes happen if the boiler be worked up to its greatest capability.

A modification of the same principle was applied some years back, by Mr. Charles Wye Williams, to wrought-iron steam-boilers, by the insertion of iron pins into those parts acted on by the heat, and projecting into the furnace and flues, so as to catch the effect of the flame. It has been well spoken of by some who have tried it, but it does not appear to have gained very general favour.

When it is necessary that the heating surface should stand within the apartment to be warmed by it, a very compact arrangement has been devised and patented, in which the conducting property of iron has been advantageously employed by the use of square blocks perforated all through from top to bottom by square openings or cells, with thin divisions between them. Several such blocks (more or less according to the size of the room and the heat required) are inclosed in an iron case or box, open at the top and bottom; and heat being applied to the outside of each block by the introduction of steam, hot water, or other vehicle, the entire mass of each block becomes heated, and imparts heat to the air contained in its cells, which then rises into the apartment—its place being supplied, and a continuous current maintained, through any fresh-air flue over the mouth of which the set of blocks

may be fixed. The blocks and their case, which may be denominated the honeycomb or cellular arrangement, will present more heating surface to the air than can be obtained within a given space by any other form. The case itself is also a valuable heating surface; and by the addition of a few ornaments screwed on its outside, a very neat and portable *heat-box* is obtained. One of the forms in which these heat-boxes have been made is represented in figure 10 perspective view, and figure 11 plan. The remarkable aggregation of heating power thus attained in a small space will be best understood when it is stated, that in a heat-box measuring 27 inches long, 18 inches wide, and 16

Fig. 10.

inches high, 80 feet of effective surface are collected. They are made of various sizes, and may be supplied with hot water from a boiler by means of pipes from one to one and a half inch diameter according to the size of the heat-box. They pre-

Fig. 11.

sent to us a very commodious method of heating rooms, halls, and staircases, and numerous situations in which they will be found practically useful. If the situation does not admit of those sizes of connecting pipes, they may be heated by steam through pipes of half-inch bore; in which case, as the ordinary forms of small steam-boilers are troublesome, and require close attention to maintain a steady temperature, the form of boiler shown in figure 3, (with the addition of guage-cock, valve, and apparatus for supplying it with water,) will be found very useful, from its working steadily for hours without attendance. The heat-box may also be heated by gas, which obviates the necessity for any boiler, but is more costly as a fuel than coals or coke. For this mode of heating them, very small pipes will suffice.

Where ventilating arrangements have been made hitherto, prior to the construction of dwellings, the cheapness of hot air cockles, and numerous other ingenious, but very pernicious kinds of stoves, have obtained for them an ill-merited preference as sources of heat; but all these *hot air* contrivances are fast giving way to the superior principles on which *warm air* appliances are constructed. In all heating apparatus, *cheapness* is only another name for *badness*;

the cheapness being attained invariably, under whatever shape produced, by a diminution of the heating surface, which therefore, in order to produce a sufficient effect, requires to be heated to so high a temperature as to deteriorate the quality of the air passing over it. All stoves are in their respective degrees open to this fatal objection—any surface of iron heated by the direct action of red-hot fuel, or the nearly red-hot products of its combustion, being subject to over-heating, without any other remedy than such small and very doubtful one as may result from the watchfulness and care of servants already occupied perhaps with other cares and duties. The temperature of boiling-water or steam is the highest degree to which considerations of health and purity of atmosphere should permit us to heat the surfaces of air-warming apparatus; but often as this has been impressed on the public mind in multitudes of scientific works, and by numerous medical authorities; from the time when Tredgold wrote, nearly twenty years ago, to this day, only one kind of stove has been produced, in which a contrivance for keeping the heat within this assigned limit has been the leading feature; which contrivance, from its requiring some nicety of adjustment, was soon abandoned by most of the manufacturers; the consequence of which is, that nine-tenths at least of the stoves now known and used as "Arnott's Stoves," though they retain the name of the philanthropic projector, and something of the outward form of his contrivance, have lost every other dis-

tinctive feature of his invention; and have no claim to any merits, beyond such as may be claimed by stoves in general. In the work which Dr. Arnott published at the time when he produced this stove, he insisted strongly on the boiling-point of water as the limit of its temperature; and he adopted means well calculated to ensure that limit not being exceeded; but in few of the stoves now imposed on the credulity of the public as veritable "Arnott's Stoves," are his self-controlling regulators (whether the mercurial, or those acting by the expansion of bars of metal) applied; and therefore the miscalled "Arnott's Stove" of the present day may be, and is, constantly worked at as high a temperature as was used in most of those cheap health-destroying contrivances which it was his aim to subvert. Some hundreds of these stoves have been closely inspected by the writer when in operation, and it is surprising, considering the excellent principle on which they were introduced, how very few of them are worked on that principle, which has been almost totally abandoned; nearly all of them, when a few drops of water were applied to their outer surfaces, betrayed, by its instant ebullition and disappearance into vapour, that the meritorious idea had been departed from, and many of the persons using them did not know that such a thing as the mercurial regulator had ever been contrived. The impossibility of raising the temperature of steam apparatus many degrees beyond the mild water-boiling limit of 212°, stamps those modes of heating with a

heating with a superiority, in a sanitary point of view, which few stoves can ever attain to.

The ventilation and warming of hospitals and asylums for lunatics is a subject requiring the especial attention of those interested in the sanitary question, whom it will not be difficult to convince that they require, *in proportion to the number of their inmates*, larger supplies of fresh air and warmth than any other class of buildings. The noxious and frequently contagious effluviæ arising from the breath and bodies of persons labouring under those loathsome and contaminating diseases of which these institutions are the wholesale receptacles, require instant removal as fast as they are generated; and the cheering influence of a pure, mild, and constantly renewed atmosphere, while it assists in alleviating the mental gloom and elevating the spirits of the hypochondriac, must also aid in soothing and subduing the furious aberrations of the maniac. For such copious ventilation as is here in constant daily and nightly requisition, spontaneous means will prove totally inadequate; the plan adopted must be compulsory, and large volumes of air, ten cubic feet per minute for each inmate, must be either drawn through the wards by the exhausting power of a rarefied shaft, or forced through by the propulsive action of an air-pump, screw, or fan.

It is not intended here to discuss very minutely, or with critical and chemical accuracy, the much vexed question whether it be best in such buildings

to ventilate by propulsion or exhaustion—on the plenum or vacuum principle—or whether a combination of both may not be better than either. It is the opinion of the writer that any one of these three modes will produce the desired result, if applied with skill; and that the choice of the mode must be determined by the local circumstances of each case. But it may be stated, in a general point of view, that propulsion is rather better than exhaustion, because its tendency is to increase rather than diminish the density of the air, and the proportion of oxygen in any given quantity of it; although, under the exhausting principle, if due regard be paid to the proper size of air-flues and channels, so as not to check the force of atmospheric pressure from without the instant the equilibrium is destroyed and the tendency towards vacuum created, no considerable attenuation of the air can take place. Assuming, then, that mechanical propulsion is to be adopted, the best instrument for that purpose appears to be either the air-pump or the screw. The fan is one which has been largely applied to the driving of air, the first attempt on record being that of Desaguliers, who applied it—of very uncouth construction, to be worked by manual labour—(not for propulsion but exhaustion) in the House of Commons, in the year 1734. The improved eccentric fan of the present day, which has been most ably described, and its superiority over chimney draft made evident, by Dr. Ure in his "Experimental Inquiry, 1836," is, however, better suited for

manufacturing than for ventilating purposes, and for getting up a *pressure* of air rather than for delivering a *quantity*. If worked at a high velocity, it makes a loud humming noise, which the air-flues convey to the most distant parts of the building; and if at a low speed, it requires a very large one to supply the proper quantity of air for a hospital. For these reasons the screw appears to be the best propeller for this particular purpose. The frontispiece contains (figure 1) a plan and (figure 2) an elevation of one, with a small steam-engine for working it, of a form which has been found highly successful on a considerable scale. Where the engine has no other but the ventilating duty to perform, greater simplicity may be attained by dispensing with the governor—the steam-cock adjusted by hand being in that case a sufficient regulator; but it would be found necessary to retain it, if the engine have other duties of an intermittent nature to perform, such as working a hoist for raising bedding or other matters to the upper stories, or for elevating patients after surgical operations in a smooth and easy manner to their respective wards; working a washing or wringing machine; and other purposes, which render an engine a very desirable adjunct in a hospital.

Favourable allusion having been made to the screw in these pages as an instrument for imparting a forward motion to air, and this good opinion having resulted from experience of its effects on a considerable scale in several cases, a few words in

explanation of its mode of action may not be out of place. Rotary motion is to be communicated to it in the usual manner, by an endless strap passing over a small driving pulley on the shaft of the screw, and also over a larger pulley or drum revolving on the crank-shaft of a steam-engine, (see figures 1 and 2) or on any other shaft; or it may be driven by a water-wheel, or other source of rotary motion; and in these respects is similar to the fan, which is frequently used for the same purpose. But though they both operate by means of rotation, their mode of action is essentially different; the fan acting entirely by centrifugal force, drawing air in at its centre, and expelling it through an opening made in the circumference; whereas the action of the screw is more directly propulsive, the air being drawn in at one side and expelled at the other. The screw possesses a small centrifugal tendency, which increases or diminishes with changes of form and pitch; but in screws of good proportions this tendency is but moderate. The efficacy of the screw as a propeller has been abundantly shewn in steam navigation; but at a great disadvantage, since this application of it hardly affords a fair comparison, (as regards our purpose) with rotary propellers; the paddle of a steamer admitting of a very large diameter, whereas the screw is limited in its diameter by the water-line at the top, and the line of the keel at the bottom; whence ensues a limitation of the size and powers of the screw as

applied to that special purpose. In ventilation, the diameter of the propeller is not often thus limited; and therefore it is an application in which the power of the screw may be more favourably developed. The quantity of air delivered in one minute by a screw 4 feet diameter, performing 500 revolutions per minute, was tested by the writer, by a delicate anemometer, and found to exceed 5,000 cubic feet; and subsequent observations on other screws have confirmed the opinion of their efficiency.

Notwithstanding these results, the screw has been condemned, in a recent well-written compilation;* but in terms so inexplicit and erroneous, as to suggest doubts whether their author has investigated the matter. Comparing the screw with the fan, he says, "it appears to be in every respect an inferior machine. The only thing in its favour is, that it is entirely *self-acting, requiring no power to set it in motion, except the ascensive force of the vitiated air itself*, which causes it to revolve, and so effects the discharge. The screw will only discharge small quantities of air at a moderate velocity." Has this writer ever seen a ventilating screw? What kind of screw that is, by whose agency vitiated air effects its own extraction, is not specified; but it is probably one of that class of agents with whose aid a pound of water is expected to lift a pound of water through

* Rudimentary Treatise on Warming and Ventilation. By C. Tomlinson; p. 190.

equal space in equal time; a feat which none of the dreamers on perpetual motion have ever yet accomplished. Any materials put together with such an end in view, will doubtless constitute a very "inferior machine" indeed. In factories where the screw is used, it is actuated, not "by the vitiated air itself" but by the steam-engine; absorbing the power of one to three horses; driving large quantities of air, and at a high velocity.

In the lunatic asylum the change of air is not required to be so very copious as in the hospital, and there seems to be no reason why compulsory mechanical ventilation should be resorted to in it, if proper constructive preparations be made in the building. It is seldom erected in a close and confined neighbourhood; there are therefore few disturbing influences likely to counteract the natural upward tendency from atmospheric pressure, through such sufficient air-channels as ought to be provided.

Plenum ventilation is highly preferable in towns and some other situations, in which large quantities of minute black sooty particles and other impurities are held suspended, either floating mechanically in, or mixed chemically with the atmosphere; its peculiar effect in such case being to maintain constantly a slight pressure or tendency *outwards*, causing air to *issue from* the room or building through such crevices or openings as may occur, either intentionally or accidentally; by which such particles are driven off from the building, and a more pure atmosphere is maintained within. The

effect of vacuum ventilation being, on the contrary, to maintain a somewhat lower density inside the building than that which prevails externally, the tendency is reversed and an *inward* tendency is established, causing extraneous matters to *enter into* the building through crevices and openings which cannot be kept perfectly air-tight, and giving rise to all the annoyances and evil effects arising from the continual influx of dust, smuts, and surrounding impurities. It will also be found very desirable to adopt the plenum in preference to the vacuum principle in many manufacturing establishments, warehouses, and retail concerns, where goods are made or stored, whose valuable quality and fineness of texture would be injured by the settlement of dusty particles upon them—an important consideration in this district, and especially so to the manufacturer whose goods are of a class which, if subjected to such deteriorating influence when in a moist stage of his operations, or during the critical process of *sizing*, (when dust will settle on their surfaces in a manner not to be easily removed,) will be depreciated in their market value.

The tendency of vacuum ventilation, also, is to create cold drafts of air into rooms through crevices, which is entirely avoided when plenum ventilation is resorted to; and though this tendency is considerably mitigated where means of ingress adequate to the exhausting power are adopted, it will still exist to some extent, and will always return in full force the instant the ingress openings are closed;

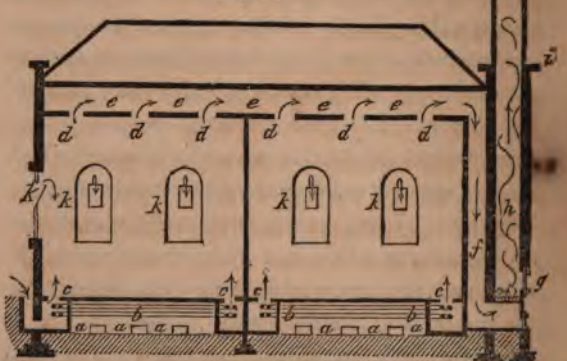
which it will occasionally be found desirable to do, as their action is subject to acceleration in stormy weather, and during the prevalence of high winds. The relative effects and tendencies of plenum and vacuum ventilation will be best illustrated and understood by noting an effect that has been found to result from their use in daily practice. If the room has been tolerably well constructed with tightly fitting windows and doors, and the doors well hung, the vacuum mode has been known gently and partially to open the door when left unfastened; on the other hand, the plenum mode forcibly replenishing the apartment with fresh air will keep the door closed, a slight pressure of air being sufficient for the purpose when acting on so large a surface as 16 or 17 feet, which is the usual superficies of a door.

But the entrance of dust and dirt, though prevented from access through windows, doors, or crevices, by plenum ventilation, must be guarded against even where that principle is employed. In whatever way air enters, dust may enter with it; and therefore, *where the advantage of purity is considered worth its cost*, the ingress flue through which air first enters a building should be provided with a diaphragm of fine gauze, stretched upon a frame sliding into a groove; a spare frame should be kept, and the frames should be daily changed for the purpose of cleaning them. Immediately in front of this diaphragm, between it and the external air, an enlargement of the air-flue should be made,

so as to diminish its velocity in that part, and permit the subsidence of extraneous matter. This enlargement or dirt-chamber should be daily watered and swept. These arrangements will, of course, cost money, and will scarcely meet the views of those numerous parties who are constantly applying to the writer for information respecting the *cheapest* plan of ventilation; but they will cost very little if provided for in the first instance, and in many cases, even where the building has been erected without any such provision, can be executed for a moderate sum.

Schools are frequently very crowded, and their atmosphere in a most unwholesome condition. The great increase in their number in the populous manufacturing districts, is a gratifying sign of the times, and

Fig. 12.



affords good reason to hope that the succeeding

generation will grow up with improved ideas and habits, and, as is most needful in those districts, stand some degrees higher than their predecessors in the scale of civilization.

Figure 12 is a section representing a boys' and girls' school ventilated (except as regards the windows) in a satisfactory manner; *a a* are the fresh-air openings; *b b*, pipes for heating; *c c*, gratings for entrance of fresh warmed air; *d d*, openings for foul air, leading into a trunk *e*, whence it is drawn down the shaft *f* by the rarifying-furnace *g*, whence it is discharged up the shaft *h* into the atmosphere.

This arrangement of a rarefied shaft, continued down to the ground for the purpose of obtaining a quick draught by a heated column, and requiring a down shaft to connect the ventilating trunk, from the top of the building, with its lower end, so that the foul air may enter it below the fire, is the same that has been adopted, at very great cost, by Dr. Reid, in the new houses of Parliament. There is a complexity and expence about this arrangement which would seem to be needless. The drawing down to the ground-level of the whole of the vitiated air of the building, and then sending it up again; the cost of connecting the main down-shaft with the up-shaft, which circumstances may require to be at a considerable distance; and the trouble of forming air-tight connecting-flues to convey the vitiated air from numerous rooms to one main down-shaft, to say nothing of the double space and materials

occupied by the two shafts, would render this plan, in numerous cases, impracticable. To overcome some of these difficulties, the fire has, in many cases, been provided for at the roof-level, (*i* fig. 12) thus relinquishing the down-shaft and the lower part of the up-shaft, and so far has been an improvement; but in many cases the trouble of carrying up fuel and ascending to attend to the fire was too great, and the ventilation was therefore uncertain. The best mode of effecting forcible ventilation by a shaft doubtless is, to adopt the last-named arrangement; substituting gas rarifiers for a furnace, as shewn in the church. (Fig. 4). By bringing the pipe which supplies gas to the burners to some accessible point near the ground-floor, with a stop-cock at that point, the handle of which should work in a graduated quadrant, the ventilation can be regulated from below with great precision.

Window-ventilation of a kind very frequently adopted in churches and schools, has been introduced into this figure (*k*, figure 12) not with a view to represent it as part of Dr. Reid's system, but to illustrate its bad effects, either where it is the sole provision made, or where it is used in combination with a better process. If it be the sole provision made, and the room be heated by a fire-place or stove, to 60°, a downward rush of air at 10°, (should that low temperature happen to prevail outside at the time,) will play upon the heads of those near it. If it be in force, as in the figure, simultaneously with proper means of

introducing fresh warmed air, its force will be modified, and partially deflected upwards, towards the egress openings; but whatever cold air thus enters, is so much deducted from that which ought to have entered warmed, through the proper channels *c*.

Many public buildings and schools have been constructed with a down-shaft for fresh air, so as to obtain it from a considerable elevation above the surface of the earth. Several of the figures in Dr. Reid's work represent such shafts, having mouths or orifices at or near the roof. The intention of seeking fresh air at such a height appears to be, that impurities settle on the surface of the ground, and therefore obtain easy access into buildings which have the orifices of their fresh-air flues situated near it. Could we carry up these fresh-air flues to such a height, that their orifices should be quite out of the reach of dust and other extraneous matters held in the atmospheres of large towns, it would doubtless be beneficial to do so; but it is, practically speaking, impossible. The writer has frequently had occasion, in the pursuit of his avocations, to visit the roofs of some of the loftiest warehouses in Manchester, many of which rise to the height of six stories, or about 70 feet; and the deposits of dust, dirt, and sooty particles, which have been there witnessed, have been fully equal to any accumulations that may prevail in the neighbourhood of well-arranged orifices of air-flues nearer the surface; and have led to the conviction,

that such shafts must be carried to an impracticable height, before the desired benefit will be fully realized.

Though the cost of more healthy modes of heating, greatly reduced as it is in the present day, is not such as to exclude them from the dwellings of those in the middle walks of life, so that they are now brought within the reach of persons of moderate income, it yet remains so great as to leave them hopelessly unattainable by the poor. But as their dwellings are usually built in clusters or long ranges, a great number occupying but a moderate space, there seems to be no reason why, in new erections for the use of persons of small income, a general system of ventilating and warming might not be adopted, common to a large number of occupants, with means of control, so that each could use it to whatever extent he pleased. This very feasible project has been shewn to be practicable, in a previous part of this paper, when speaking of cottages adjacent to factories; but where they do not possess that advantage of contiguity to steam power, spontaneous principles of ventilation must be resorted to, and means of heating adopted which require less attention than a steam boiler, unless it be of the kind shewn in figure 3. Hotwater apparatus for heating air admit of the easy fulfilment of these conditions, and the cost being divided among a large number of dwellings, and previously planned, would not cause any very serious addition to the rental. The present mode of clustering such cottages toge-

ther, without any provision for the supply of that vital element which is as necessary to the poor as the rich, calls loudly, especially in towns, for a discontinuance of that neglect which has so long prevailed respecting the health of the working classes; to the evils of which, the public mind is being happily aroused; and the feeling is fast gaining ground, that the health of the masses has a strong claim on the public sympathies, and is a fit subject for legal enactment.

True it is that the poor man, when overtaken by sickness, can find hospitals where ample sanitary measures have been taken for his benefit; true, that when left utterly destitute by old age or misfortune, the asylum of the workhouse is provided by the laws of his country, in which the subject of health is to some extent cared for; true, also, that should he turn out a malefactor, till his misdeeds demand that he should be separated from his kind and confined within the four walls of a cell,—even there does a misplaced philanthropy solicitously provide him with a costly prison, replete with appliances for warming, ventilating, and other purposes more costly still than these, which the honest and industrious are heavily taxed to pay for. And so far it is, perhaps, well; but it remains a remarkable fact, and a singular anomaly in our social condition and ways of thinking, that so long as he remain strong and honest, able and willing to earn his daily bread by the sweat of his own brow, his dwelling may be a cellar, a kennel, or a sty;

he may be living in the midst of pollution, and surrounded by subtle, dangerous, death-dealing influences subversive alike of health, comfort, and moral elevation, which neither philanthropy nor law have, till very recently, largely assisted to remove. Highly cheering is it, however, to perceive that our legislators and men of influence are opening their eyes to these vital subjects; and from the increasing amount of discussion on sanitary questions that has arisen in Parliament and among public bodies, there is reason to hope that the question will acquire a growing importance, whether we have not begun at the wrong end, and whether the first efforts ought not to have been directed towards improving the domestic condition of the honest and industrious poor; on the principle that "prevention is better than cure," and that industry has a claim on our sympathies prior to, and stronger than, that of crime. The establishment of baths and wash-houses,—the erection of large buildings, to be subdivided and let out as model lodging-houses in small portions as "workmen's homes," provided with means of comfort, cleanliness, purity of atmosphere, and proper temperature, on the large scale so as to reduce the individual rental,—the numerous sanitary laws lately passed,—the measures in course of adoption for providing increased supplies of water to towns,—the reductions universally taking place in the price of gas,—all these things, and many more, show that minds and influences are working towards the improvement

of the masses, and that a change is taking place, which cannot fail to improve the condition, and with it the ideas and habits of the working and poorer classes; and it is to be hoped that legal measures for the sanitary improvement of their dwellings, compulsory on landlords, will ere long be adopted; if, indeed, they be not anticipated by a wise spirit of speculation arising among owners of cottage properties, and the judicious application of capital to the remunerative amelioration of the dwellings of the poor. It is not here pretended that the want of fresh air, water, light, cleanliness, and warmth, is the principal cause of prevalent wretchedness and crime among the poorer classes; of these, the chief sources will be found in human passions and imperfections. But there is abundant proof that it is a predisposing cause thereto; and the end of these latter remarks will be answered, if they succeed in striking a blow (though but a feeble one) towards the demolition of *one* only of those insidious, yet too fatal causes, which often lead the erring mortal from what might have been his comfortable and cleanly hearth to the ale-house and dram-shop,—from which it is sometimes but a short step to the workhouse or the gaol.

Reverting to the subject of gaols and prisons, the cellular construction and minute sub-division of which (and frequently also, their material being stone) renders any but a previously planned adaptation *impossible;* great improvements have of late years been introduced into their ventilating and

warming arrangements, by the application of the hot-water mode of heating, which, as before explained when speaking of churches, is the most suitable for buildings of great length, except where mechanical power is resorted to. They are generally buildings of three or four stories. Pipes should be conveyed the whole length in a chamber under the corridor of the ground floor, constructed of proper size to contain them, supplied with fresh air from all sides of the building, so as to be operated on favourably by the wind from whatever quarter it may blow. From the upper part of this chamber, separate vertical flues, of about nine inches by six inches, should run up in the wall that divides the cells from the corridors, one flue to each cell, opening into it near the door just above the floor. At the other side of each cell, near the ceiling, an egress opening should communicate with a separate vertical flue, conveying the vitiated air into a horizontal trunk in the roof, which may be exhausted by a shaft rarefied by fire or gas, as explained when speaking of schools.

The plan of rarefaction and exhaustion is the one that has been of late years most usually adopted in prisons, in which it has been effected by a central ventilating shaft of very large dimensions, heated by a fire near the ground level; the buildings radiating from this shaft in four or five divisions, a vitiated-air trunk is brought down from the top of each division into the bottom of the shaft, under the fire-grate. The cost of this process, and its

inferiority to mechanical means, are pointed out by Dr. Ure in the "Enquiry" previously referred to.

Another feature of prison-ventilation which has been frequently adopted, seems to be attended with needless complexity, and diversion of the air from its natural course. It consists in forming the air flues in such manner, that the fresh air (warmed in winter) enters at the top of each cell, and the vitiated is withdrawn at or near the floor-level. In so small a room as a prison-cell, seldom containing more than 600 cubic feet, built with thick walls on all sides, having but one very small window, and occupied by only one person, there cannot be any very serious advantage gained by such a circuitous arrangement, either as to uniformity of temperature or purity; and although it doubtless will effect a somewhat more complete mixing of the fresh air with the impure, it is questionable whether the quantity inhaled will be any purer on that account; and therefore there seems to be no sufficient reason for departing from the greater simplicity and more natural arrangement, of introducing air at the bottom, and withdrawing it at the top. On the whole, the reflecting mind, after passing through any of those expensive bastiles of which so many have been erected of late years throughout the country, will observe with regret, that these and other costly refinements are enforced by government authority for the benefit of the *felonious*, and are for the present wholly beyond the reach of the *honest and industrious* poor, who have not by misdeeds come

under the cognizance of the law; who are content to live on in a manner that is useful to mankind, and consistent with the welfare of society; yet, as to their health, cleanliness, and personal comfort, uncared for and neglected in the statutes of their country.

Collateral to the question of rarefied shafts for extraction of air, is that of chimneys in dwellings; which, instead of assisting, as they might do, in the purification of apartments, frequently fill them with smoke. Were the same principles carefully kept in view in those of dwellings, that ensure a proper action in factory-chimneys, the same satisfactory performance would be the result. Why do we so seldom hear of a factory chimney refusing to perform its office? and whence does it possess this immunity from annoyance? Because care is taken to supply the furnace freely with air *at the bottom*, admitting as little as possible over the fire; because it is made straight, high enough, and large enough, for the smoke it has to carry, with a smooth and generally round interior. A factory chimney ought not to be expected *(cæteris paribus)* to draw so well as a house chimney, the flue frequently taking a *horizontal and tortuous course, with sharp angles*, through and around the boiler for 80 or 100 feet before it begins to ascend. Air at the bottom, height at the top, and adequate sectional area are the principal requisites.

As to access of air (the want of which is a frequent cause of smoky chimneys);—if fresh-air flues of

sufficient size be constructed (as suggested in the earlier portion of these "Hints,") leading into each room, the ventilation will, in addition to its own proper function, subserve the very important object of aiding the chimneys. Since smoke-channels cannot (as usually led up) be made straight, from having to pass fire-places over them, their divergence should be the smallest possible, with easy curves, and their sectional form should be either round or oval (not oblong), for which, and for being easily cleaned, earthenware tubes afford great facilities. These points being attended to, the fire-places and throats properly constructed, free from sharp angles, and funnelled gradually up to the flues, and the flues well-proportioned to their respective grates, there is only one other liability to be overcome, viz:— that of being over-topped by hills, trees, or adjacent buildings, which may direct the wind downwards into them, and which will often require the chimney to be carried up higher.

A suggestion may be here offered, whether better provision might not be made for carrying off smoke and vitiated air than has been usually attempted, and without great increase of cost. Let *a*, figs. 13 to 16, represent a square, round, or oblong chimney, large enough for all the smoke of a house, carried up through its centre, where the walls intersect each other; or, in small tenements, in the centre of one side. Let it be wholly (as in figures 14, 15,) or partially (as in figure 16) surrounded with ventilating flues of egress from the various rooms, and

carried up, say eight or ten feet above the ridge. Let all the grates be of the register kind (or of the ordinary kind, furnished with a tightly-closing Wilson's chimney-valve), opened only when in use; and let their chimneys be carried up straight to within a foot of the cornices of their respective rooms, at which point let them each turn off, at an angle of 45°, upwards into the main chimney. Close under the cornice over the grate, fix an Arnott's valve or sliding regulator, leading into one of the egress ventilating flues; a door should be left at the bottom of the central main chimney, for cleaning. By this plan, which assimilates the chimney to that of a factory on a small scale, the ventilating flues will be rarefied by the waste heat of the fires; and if we suppose the kitchen to be

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

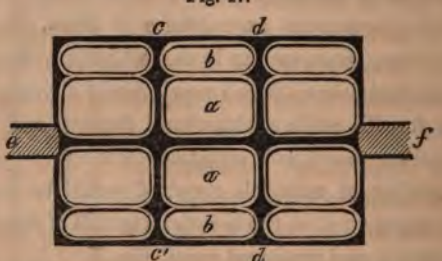
in one of the lower rooms, this rarefaction will be constant. The divisions may be of stout sheet-iron, or of slate. The height given to the chimney and egress flues will, it is intended (the latter being rarefied on one side by the former, and assisted by proper ingress flues), ensure the draft of them all and that of the fires; and in buildings of superior class, that portion of the stack appearing above the roof, might be made a prominent ornamental feature, susceptible of the highest degree of architectural embellishment. In buildings of a lower class, it might be left comparatively plain, in which case it would still have a more respectable appearance than those heterogeneous assemblages of pipes, elbows, and chimney-pots, various in shape, upright, oblique, zig-zag, and askew, which now present a ridiculous contrast with noble architectural façades, and disgrace some of the best situations in the metropolis. The additional materials required would be small, and compensated by the beneficial results of freedom from smoke and improved ventilation.

It will be observed, that by this plan those spaces in a chimney-breast which are usually occupied by masses of solid brick-work, and by thick divisions between separate chimneys, would, by their conversion into air-channels, be made to subserve the purposes of ventilation.

Now that the brick duty has been remitted, hollow bricks with thin sides, or earthenware and stoneware tubes, might be moulded at a moderate price to similar forms, so as to be built up with

little care and labour; and if gas-lights be used in the rooms, the hot products of the combustion may be led with facility into the egress-flues, and increase their rarefaction. In cases where the height required above the roof for the main chimney cannot possibly be had, the same principle may be partially carried out by leading up the chimneys separately, as at present, constructing them of large hollow bricks or double tubes of this section. Figure 17 represents a stack consisting of six such double tubes for six rooms, securing for each room its separate chimney and egress air-channel: *a a* are chimneys;

Fig. 17.




*b b*, egress air-flues. For greater certainty of action, however, a tall chimney should be adopted wherever practicable; and it may be easily adopted in conjunction with this arrangement of earthen tubes, by simply adding a few lengths above the roof, hooped round the top, and kept securely in their places by attachments to two strong iron uprights in the interstices. The double-tubes might be formed into easy curves while in the plastic stage of manufacture, so as to allow them to pass each

other on the different floors. In a dwelling three stories high, for instance, consisting of six rooms, or two dwellings of three rooms each, the whole of the six chimney-tubes and ventilating flues may be carried up in one tubular stack; the tubes, as they proceeded upwards, would be firmly tied together and secured by the floors, and at the top, outside the building, might be held together by an iron hoop, concealed by an ornamental moulding. In the two lower stories, the egress-openings would not be in the centres of their respective chimney-breasts; but as they would each require a valve or sliding-plate with a frame of iron or brass, another and similar frame might be fixed at an equal distance on the other side of the centre line. The hollow spaces that would be left under the elbows should be filled in with brick-work, and the front and sides of the whole mass plastered, which completes the chimney-breast all the way up.

In dwellings, a usual size of chimney-breast containing three flues is six feet two inches across the front, with a projection of one foot seven inches: constructed on this plan, with smoke flues of the usual size—14 inches × 9 inches—and air-flues 14 inches × 3 inches with rounded corners, it would only measure, for a fire-place three feet wide (sufficient for a room 20 feet square) 5 feet 9 inches × 1 foot 4 inches, thus gaining an increased space on each side of the breast of $2\frac{1}{3}$ inches, and by diminished projection, adding three inches to one dimension of the room. Another frequent

size for three flues is 7 feet × 1 foot 4 inches, in which case there is no addition to the size of the room, but a saving of $7\frac{1}{2}$ inches on each side. If the fire-place be only 32 inches wide (sufficient for a room 12 feet square) the size of breast will be still further reduced 2 inches on each side. The width of the breast being reduced, a mantel-piece one size smaller would suffice in each room; and it is confidently believed that the saving of brick-work and marble would nearly balance the cost. The larger or smoke-tube should be glazed inside, to reduce friction, and the outside of the double tube should be left rough, or scored, so as to afford a firm hold to plaster. The tubes should be rebated at the ends, so as to form, by the use of a little cement, a smoke-tight joint, and be easily built up in lengths one on another.

The cost of such double tubes, made of strong fire clay, as ascertained from respectable manufacturers, would probably be about 1s. 9d. per lineal foot, subject to possible reduction that might be effected by practice and quantity.

By inserting in the interstices $c\ c^1\ d\ d^1$ one brick breadth, ($4\frac{1}{2}$ inch work,) a recess for the grate 27 inches wide is obtained. If two brick breadths (9 inch work) be inserted, an opening of 3 feet wide is gained. These insertions, however, need not be carried higher than 3 feet under the ceiling of the upper rooms. In order to prevent communication of heat through the sides of the breast, it may be found desirable to run up a slight

thickness of brick or tile outside them. This would lessen the saving of space, but might be otherwise beneficial.

The advantages of this mode of obtaining (in connection with proper fresh-air arrangements) egress for vitiated air, and improving the draft of fire-places, which has suggested itself to the author while writing this little treatise, may be summed up as follows:—Improvement of smoky chimneys; vitiated air effectually removed, and size of chimney breasts reduced,—and this at a very small increase of cost, estimated *at most*, not to exceed 40s. for a room 20 feet square, including brass frames and other accessaries, executed in a manner suitable for the dwellings of the middle classes, and less for smaller houses.

Offices in banks and mercantile establishments present great difficulties when their effective ventilation has not been considered during the erection of the building. For convenient access, they are usually situated on the ground-floor; seldom higher than the first floor. In banks, the upper stories are frequently fitted up in a style of elegance consistent with the abode of a superintending partner or resident manager; and in warehouses, are devoted to the storage of merchandize, often to the height of six stories. The proper egress-flues for rooms so situated might easily have been carried up in the walls at first; but to make them afterwards is so expensive, and causes such disturbance of existing arrangements, as to leave the ventilator

no resource but to trust to the windows and occasional opening of doors as means of ingress, and to the weak and insufficient exhausting action of one, or at most of two, common fire-place chimneys, as his means of egress; and this frequently where there are from 20 to 40 clerks sitting the whole day, with from 12 to 20 gas-lights (in winter) adding their contaminations for several hours. In some cases, in lofty warehouses, broad channels have been cut out in the walls all the way up, and hollow bricks inserted, so as not to impair their strength; but if a sufficient quantity be inserted, the operation is so costly, dirty, and troublesome, that it is seldom consented to.

The intelligent reader will have perceived in the course of this treatise, that there are two modes by which ventilation is effected—the one spontaneous, the other compulsory; the spontaneous mode depending entirely upon such currents as may be caused by the action of winds, or by the temperature within exceeding that without the building, and therefore not to be depended on for constant and certain performance, especially in summer and still, close weather, when its aid is most required; the compulsory mode depending on some active agency imparting motion to the air whenever put into operation, and therefore requiring some moderate trouble and attendance.

Compulsory ventilation may be sub-divided into two classes—natural and mechanical: natural ventilation being effected by the immediate action of

heat on the air, changing its specific gravity, destroying its equilibrium, and thereby causing motion. This is best done in an upright shaft open at the top, the air in which is rarefied by fire or gas. Mechanical ventilation may be performed by the operation of machinery or instruments worked by steam or other motive power, such as the falling of weights, the flow of water, the movement in a circle of horses or other animals, or by manual labour. Ventilation by the falling of weights has been tried and rejected, owing to its requiring either an enormous weight, or else a deeper fall than can be had, to move a moderate quantity of air; and also owing to the labour of periodically winding up the weight. The idea was probably borrowed from clock-work, but would hardly have been pursued had due regard been paid to the very small amount of *work* required from a large clock-weight,—the seconds' hand revolving only once per minute, and the short hand only once in twelve hours; whereas any fan or blower, to be effective, must perform, at least, 100 revolutions per minute, or 6000 per hour,—the relative requirements of speed being as 1 to 100, to say nothing of friction and weight of air to be moved. The same reasoning applies to spiral springs, which have been suggested as a motive power for ventilation. Manual and animal labour are intermittent, therefore objectionable, and for most purposes superseded by that more indefatigable agent, steam; though it is not long since the writer saw a donkey

laboriously circumambulating about a post in the performance of his appointed function of blowing a foundry furnace by a fan; and horses are still employed by some builders to grind their mortar. Water-power may be used advantageously where there is a constant fall sufficient to turn a wheel, or to actuate a water-engine; but steam-engines of small size are now so moderate in price, and so well understood, that in most cases they are to be preferred as the moving power where mechanical ventilation is adopted in large buildings, conjointly with the performance of other mechanical duties.

Another species of mechanical ventilation has been introduced by Mr. Gurney, by the injection into a shaft of small jets of high-pressure steam, which immediately expanding and filling the shaft, are carried up by the high temperature of the steam, which thus draws after it the air in the lower part of the shaft. This being connected with any system of egress-flues, insures their action by exhaustion, and will be found to answer well in many cases.

This steam-ventilator is in constant use at the Orrell colliery, near Wigan. A cylindrical boiler of 24 horses' power, twenty feet long, by six feet diameter, is set in brick-work in the usual manner above the ground near the mouth of the up-cast shaft, which is 900 feet deep. A pipe proceeds from this boiler down the shaft to a depth of 600 feet, where it turns off into a drift or passage sloping downwards, and leading into some of the

galleries of the mine. At a distance of 14 feet along this drift the pipe is divided into four smaller branches, each of which stands up across the drift, and is perforated with three apertures fitted with conical mouth-pieces. These mouth-pieces or jets (twelve in number) point upwards in a direction parallel with the floor of the drift, and are so spaced in their respective pipes as to be distributed equally over its entire sectional area. The boiler supplies steam at a pressure of 50 lbs. per square inch, which is considerably reduced before it reaches the jets by condensation within the pipe, which ought to be lapped. The steam issuing from these jets expands conically, the bases of the inverted cones of steam occupying space in the shaft, and acting on the air as pistons; the jets by their upward force also communicating motion to the air laterally, much in the same manner that a running stream of water communicates motion in the same direction to standing water in its immediate vicinity; or as the air in a chimney is drawn out and carried on in the same direction as the prevailing wind. (See figures of Chowne's air-siphon in a subsequent page.) Probably upward motion is also imparted to the air on the principle of continually-expanding concentric rings of steam curling over each other as they issue from the jets, and drawing air into the inverted cones of steam, whence it is driven onward as before described. These several causes combine with the high temperature of the steam in producing

an upward motion within the main shaft; just as the steam discharged from the blast-pipe into the chimney of a locomotive causes a strong current of air to follow through the fire-bars. The above arrangement of steam-jets and general mode of ventilation has been also adopted at the Seaton-Delaval Colliery, near Newcastle-on-Tyne.

From data kindly supplied by Mr. G. Gilroy, viewer of the Orrell colliery, the absolute effect produced by this arrangement, as indicated by the anemometer, amounts to 46,143 cubic feet of air passed through the mine per minute, being equal to 1922.6 ft. per horse per minute. This result, taken in connection with the power required to produce it, is considerably below that which has been obtained by the writer with a double-action air-pump, which passed upwards of 13,000 cubic feet per minute with a power of four horses, being equal to 3,250 ft. per horse per minute. The difference may probably be owing to the more indirect action of the steam-jets upon the air, which can hardly be expected to operate with the same efficiency as when the expansive energy of steam is confined within a cylinder, and concentrated upon a piston fitting closely into it, as in the steam-engine; but before any just comparison can be made, more precise experiment must be instituted. The avoidance of all machinery on the steam-jet principle is an argument in its favour in many cases.

Ventilation has been also divided into plenum and vacuum, as before stated (p. 49); the former

consisting in forcing air in, the latter in drawing it out. There has been much discussion as to the respective merits of these two modes, and it seems to be yet quite an unsettled point among the disputants, whether it be best to apply the motive agent at the ingress or egress end of any system of air-flues. An opinion has been previously expressed in page 49, that with such exceptions as are stated in page 53, it is a matter of little moment, and that the choice may be determined by local circumstances; provided that they admit, in the event of the vacuum principle being adopted, of the ingress-openings being of large size, so as to prevent any injurious attenuation of the air, which would be caused by their checking the immediate tendency of the atmosphere to rush towards the void thus created beyond the egress openings.

Gas may be made, as we have seen, (pp. 26, 58,) an important agent in ventilation; effecting the compulsory withdrawal of vitiated air, by producing a powerful rarefaction in the lower end of an upright shaft. From its cleanliness and safety, the great facility with which the degree of rarefaction may be regulated by a cock fixed in any convenient position (see p. 58), and the small size of the pipes necessary for its conveyance, it offers many advantages which have been extensively made use of. The public voice has been loud and effectual in many places, in obtaining reductions in its price; and gas companies are, by slow degrees, opening their eyes to the increased profits to be derived

from supplying it for lighting purposes at such a price as to bring it within the means of classes of persons whom the cost has hitherto debarred from its use. And it is necessary they should do so; for this most convenient mode of lighting a house is not yet accessible to the masses of the population, and its adoption for *ventilation*, for cooking purposes, and for other uses, is still in a state of infancy. Fertile minds are actively at work, seeking to cheapen the existing gas-making process, and diving into chemical researches in order to obtain gas from less costly materials; others again are for supplying gas-making apparatus on a small scale for individual use; oil and water are both put forward as cheaper means of supplying gas than coal; and the electric battery threatens to set aside the purifier and the retort. These are all influences tending to bring gas to that price which will enable it to play a more important part in the process of ventilation.

But the application of gas to ventilating purposes must, till improvements are effected, be confined to the egress of air;—as a means of warming it where it has to be breathed, the gas stoves frequently met with are highly objectionable. They usually consist of a spiral coil of tube, having small perforations from which the gas issues in small jets, where it is ignited. The coil and flame are concealed by an ornamental cylinder (used solely for the purpose of concealment), and the products of the combustion are discharged into the

apartment to mix with its atmosphere, and be inhaled by its inmates. These products consist (in the case of coal gas) chiefly of carbonic acid gas and water. The deleterious effects of breathing this gaseous product are now so well known as to leave it scarcely necessary to mention that it is the gas which has often proved fatal to persons sleeping in a confined room where it has been evolved from a pan of burning charcoal. Gas stoves should never be used unless their joints be made perfectly gas-tight, so as to prevent their poisonous products from escaping into the apartment, and unless the stove be connected by a tube with some well-drawing chimney or egress ventilating flue. If taken into a chimney, it becomes an expensive mode of heating from the serious abstraction of heat carried off with the hot products; but if taken into an egress flue, the heat of the escaping gases is made available for the rarefying of such flue, and removing air vitiated by other causes.

During the last winter, the writer had occasion to visit a workshop 60 feet long, 20 feet wide, and 10 feet high, in which 80 clothiers sat cross-legged for 10 or 12 hours daily, packed as closely together as the performance of their duties would permit. This room was heated at one end by a kind of ironing-stove used for heating their implements of trade, and the other parts by two of these gas stoves, which were discharging into the apartment the vitiated products from 120 gas jets, without any separate provision for carrying off those products;

prove inadmissible in most cases. This is, doubtless, a radical cause why Arnott's and other stoves are constantly over-heated: they are made and applied of sizes that will not produce the necessary effect unless the temperature of their surfaces be elevated beyond that proper limit. Dr. Arnott himself may be supposed to have had perception of this; for in those excellent stoves which he contrived for the London Custom-house, ably described and illustrated by an entertaining and instructive historian,* he effected a multiplication of heating surface without very great increase of bulk, by the addition of vertical air-tubes passed through the interior of the stoves from top to bottom. Notwithstanding the diminution of size (as compared with surface) thus effected, we are told by the same author that "the display of their lumbering masses has much impaired the architectural elegance of one of the most spacious and handsome rooms in the metropolis." Hence, *stoves of a wholesome temperature*, if of any of the usual forms, cannot well stand in the rooms they are to warm without disfigurement.

But to return from this digression to the subject of heating by gas,—there are several plans now before the public, all pointing more or less to its general introduction into dwellings for other purposes than those of lighting. Gas made from oil by English's apparatus, and the hydro-carbon gas

* Bernan. "History and Art of Warming and Ventilating," vol. ii., pp. 229 and 232.

made from water, are put prominently forward by their respective advocates as more readily admitting of manufacture for private and domestic use on a smaller scale than coal-gas, for the various purposes of lighting, cooking, and warming.

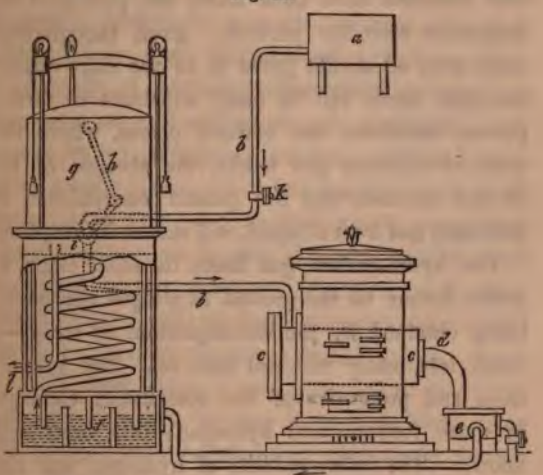
English's olefiant gas is made from oil, of which the commoner kinds and coarser qualities will supply the gas; but the more liquid the nature of the oil, the less liable to clog will the small pipes and cocks be through which it must flow on its way from the cistern to an oval or cylindrical retort.* Falling into the hot retort drop by drop upon an iron plate or bars, which accelerate the vaporization by subdivision of the liquid, it is there decomposed and resolved chiefly into one or more of the carburets of hydrogen, leaving a residuum of carbon in the retort. The condensable empyreumatic vapours being small in amount, the gas passes directly into a small siphon-box which collects any undecomposed oil which may have passed over, whence it may be daily withdrawn and recommitted to the cistern, from which it passes again through the retort. From the siphon-box the gas passes into a washer, in which it is compelled by a series of vertical plates to take a sinuous course, alternately ascending and descending through water, to the gas-holder. The chief peculiarity in the process adopted by this company consists in a jointed lever attached to the top of

* A very pure vegetable oil for this purpose is sold at 1s. 3d. per gallon, by Mr. Skelton, Market-street, Manchester, who also sells the apparatus.

the gas-holder, by means of which it is made, as it rises and falls, to close or open a cock in the pipe through which the oleaginous liquid flows from the cistern into the retort; thus proportioning the supply of oil and quantity of gas made to the immediate demand. Manufacture and consumption thus going on at an equal rate, the necessity for large gas-holders or receivers is abolished. The fire-place is so constructed that the fuel is put in at the top; and if coke broken into small pieces be used, it may be charged to the top, and the fuel will continue to settle down upon the fire as required for some hours without attendance. The residuum of carbon left in the retort may be removed daily; and an advantage will be derived from the use of this gas when manufactured on a small scale for a single dwelling, in its doing away with the bulky residuum of coke left in retorts after the destructive distillation of coal. If of very small size for three or four lights only, the retort may be fitted in a horizontal position into a neat cast-iron stove lined with fire-bricks. The cost of the apparatus is about one pound per light if 20 lights be required; but if below that number, it bears a higher proportion. Figure 18 represents the apparatus for making this gas. *a* is a cistern containing the oil, which flows through the pipe *b* into the retort *c*, whence the gas issues through the pipe *d*, the siphon-box *e*, and the washer *f*, into the gas holder *g*. *h* is the jointed lever working the stopcock *i* which regulates the flow of oil, and

*k* is another cock to be closed when gas is not required. *l* is the pipe leading to the burners.

Fig. 18.




This gas, though it appears to be less troublesome in the manufacture than coal-gas, from the absence of tar and of coke, is probably on the whole not much less expensive. As large a quantity of heat as is required to distil a cubic foot of gas from coal will, probably, be also necessary to produce the same quantity from oil; with this disadvantage as regards cost, that the oil leaves behind it in the retort no coke nor other residue of marketable value. At the Harrow station of the North Western Railway, where this Company's apparatus has been used more than twelve months, it is said that the cost of their gas is not very different from that of coal gas; but before the

former shall have become very extensively used, decisive experiment and comparison on this point will doubtless have been made and published by competent scientific persons. Even though that made from oil should prove to be the more expensive gas, there will be many situations in farms, private mansions, and country places, where the want of adjacent gas works, the absence of tar in this method, and the greater convenience of obtaining gas from a liquid, will secure its adoption.

The hydro-carbon gas bases its chief claim to public favour on the ground of alleged cheapness, being obtained by the decomposition of *water*—a much less costly material than oil. The proportions and properties of the constituent elements of water (oxygen and hydrogen) have been long known. The inflammability of hydrogen was also long ago illustrated in a scientifie toy of Dr. Priestley's, which he called "the philosophical candle," consisting of a bladder filled with this gas, and furnished with a stop-cock and tube at the end of which the hydrogen gas was burned. Several patents have been recently taken out for the manufacture of hydrogen gas from water, and for its application to lighting and heating; but they do not appear to possess any remarkable novelty in the mode of obtaining this gas. They all proceed on the well-known methods of dropping water upon very hot iron filings in the presence of charcoal, whereby the water is decomposed and the hydrogen set free, (the oxygen uniting with the iron

forming an oxide of iron, and with the charcoal forming carbonic acid gas); or by passing the vapour of water over iron filings or charcoal intensely heated in a retort, whence the same combinations and liberation of hydrogen ensue. This mode of obtaining inflammable hydrogen gas has been so well explained and graphically illustrated in an elementary treatise, published more than twenty years ago,* and known thirty years before that time, that it need not be here dwelt upon further than to say, that the process there described is the same in principle (with some variations in detail) as those more recently brought forward. If there be any valuable novelty, therefore, in these latter, it must be sought for in the purposes to which the gas is to be applied, or in the mode of applying it, rather than in the process of its manufacture.

In the first-named of these plans, (producing hydrogen by drops of water falling on heated iron,) the best process appears to be this:—A cylindrical retort is set up in a furnace in an upright position, at the lower end of which is a flat mouth-piece at right angles with the cylinder, and passing out through the brickwork, furnished with an iron door for the purpose of cleaning the retort. The upright cylinder is divided into two parts, the division not quite reaching to the bottom, so as to permit the passage of gas under it from one part into the other. In one part are placed iron

* "Dr. Graham's Chemical Catechism." 1823.

filings, coarse turnings, or iron wires, so arranged spirally or otherwise as to intercept or subdivide water falling upon them, and bring it instantly under the action of as large a heated surface as possible. These are arranged on one side of the division, and pounded charcoal on the other. Water is introduced from a cistern through a small pipe furnished with a stop-cock partly closed, so as to cause it to fall in drops or in a small stream upon the iron. It will be slowly decomposed by contact with iron at a moderate temperature; but to separate it into its constituent gases with the rapidity necessary for practical uses, the iron must be kept *at a nearly white heat.* The hydrogen and such portion of the oxygen as is not taken up by the iron, pass under the division and up through the charcoal, which absorbs a further quantity of oxygen, forming carbonic acid gas. Mixed with this, the hydrogen passes away through a series of siphon-pipes to cool it, into the gas-holder. By passing these mixed gases through a purifier or box containing lime, which takes up the carbonic acid and forms a chalk, the hydrogen may be obtained in great purity; but at a sacrifice of probably one-sixth of the whole quantity of gas.

This gas burns with a pale blue flame, accompanied with great heat. It is therefore most fitted for heating or cooking, or for rarefying a shaft for extraction of vitiated air. But, as will be presently shewn, it must not be used for heating *air that is to be breathed,* except through the

intervention of a gas-tight stove furnished with a chimney-pipe, to keep separate and remove the vitiated products of combustion. In its application to lighting purposes, its luminous properties are so feeble as to require admixture with carbon; to generate which, a separate retort, heated to a lower temperature by the flame dismissed from the water-retort, is necessary; with cistern, pipe, and stop-cock, to afford a regulated supply into this second retort, of any resinous liquid from whose decomposition the carbon is to be obtained. This involves a complexity and multiplicity of parts, unfavourable to the employment of this gas on a domestic scale for lighting purposes, which will militate less against its use on a larger scale. This is the method adopted by Mr. White; including some improvements introduced by Messrs. Hall and Wilson; who have also introduced into the retort vertical iron ribs, cast on its inner surface and projecting into the space occupied by the filings and charcoal, whereby the heating surface is considerably increased and brought into more intimate contact with those materials. These ribs also tend to prevent frequent casualties which have occurred in this process from the tendency of white-hot cast-iron to split when water is dropped upon it; any fissure in the retort being fatal to that part of the apparatus, from its allowing the gas to escape into the fire and up the chimney.

Another mode of obtaining hydrogen gas from water is, first to convert it into steam, in an

ordinary steam-boiler, and thence discharge it into a nearly white-hot horizontal cylindrical retort through numerous jets, playing upon a surface of broken charcoal. This is the process adopted by M. Gillard, of Paris, but it does not appear to be entirely new. It is so far precisely the same as that illustrated by Dr. Graham, but substituting charcoal for iron filings. The intense heat decomposes the steam, its oxygen combining with the charcoal and forming carbonic acid, which passes off in a state of mixture with the liberated hydrogen, but is afterwards separated from it by absorption in its passage through a purifying box containing lime. In this state the gas is ready for use for heating and cooking purposes; but if required for lighting, its illuminating powers must be increased; which is effected by M. Gillard, not by admixture with carbon as in White's process, but by using an argand burner, from which the gas issues in a circular series of small holes, within which he fixes a circular net-work of *platinum;* a metal most difficult of fusion, and therefore comparatively indestructible by the heat of the gas.* It is capable of being maintained *at a white heat* for an immense length of time, without any apparent loss of material; and this property has been long ago made use of for a purpose very closely similar, to increase the power of the oxy-

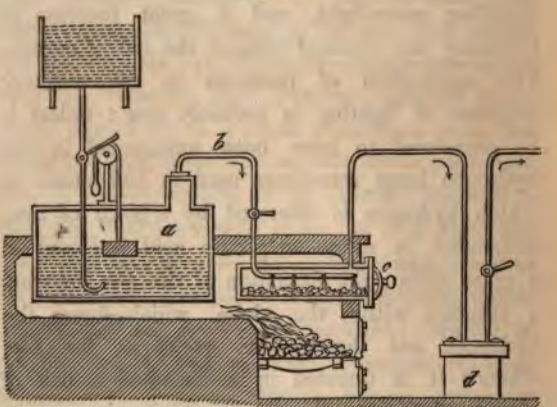
* Gas made by this process has been largely applied to various purposes by Mr. Kurtz, at his chemical works, Cornbrook, Manchester.

hydrogen light exhibited in London and elsewhere, by uniting hydrogen with oxygen in proper proportions, in the presence of lime under a cage of platinum; whereby the light developed by the combustion was greatly increased in its intensity. By this simple means a pure white light resembling moon-light, and a great increase of brilliancy are obtained without the aid of carbon. This application of platinum to the ordinary purposes of lighting is probably new: unless it be considered to have been anticipated in the hydrogen lamp sometimes used in bed-rooms, in which hydrogen is liberated by a piece of zinc, suspended in dilute sulphuric acid enclosed in a glass globe; the formation of the gas inducing a pressure within the globe, which forces the hydrogen out through an orifice at the top, whence it is directed in a jet upon a ball of spongy platinum, which it maintains in a state of incandescence.

In places where a steam-boiler exists for other purposes, steam may be obtained from it for this process; where there is not that advantage, a special boiler must be applied behind the retort, and heated by its waste heat, as described for the carbon retort in White's process. This, however, renders it liable to the same objection of complexity and multiplicity of parts, and in a greater degree, as it would always be required; whereas White's process does not require the second retort, except when used for lighting. In

Figure 19, which represents Gillard's apparatus, *a* is the steam-boiler, *b* the steam pipe terminating in jets in the retort *c*, whence the gas passes through the purifier *d* to the gas-holder, and thence to the burners.

Fig. 19.




Let us now pass from gas made from oil and water, to that made from coal, which is the gas in general use in towns and factories. The process for making it is more simple than in either of the hydro-carbon plans, but less so than in that where oil is used. It consists of a retort or horizontal cylinder, in which coals are enclosed, and subjected to heat of a lower temperature than is necessary for the decomposition of water. The gaseous constituents of the coal are separated by the heat, leaving the solid matter of the coal in the shape of coke in the retort, and pass

off through pipes and vessels immersed in air and water, which cool, condense, and detain the tar, ammonia, and some other vapours; but which cannot detain the non-condensable products, consisting chiefly of carburets and sulphurets of hydrogen, and compounds of oxygen and carbon. These are passed through purifying vessels containing lime and water, which absorb the sulphur and carbonaceous compounds, leaving the hydrogen and sub-carburetted hydrogen gases to pass into the gas-holder ready for use.

In comparing the merits of coal gas with those of water gas, the greater simplicity of the generator for coal gas is obvious. Both its constituents (hydrogen and carbon) are obtained by one process, in one and the same retort; whereas, in White's hydro-carbon process, two retorts are necessary to obtain an illuminating gas; and in Gillard's, a retort and a steam boiler. In White's process, where the gas is used solely for heating and cooking, one retort is sufficient; but in the majority of cases where gas is made at all, it will be required as much for lighting as for those other purposes. The simplicity, in this respect, of the coal gas manufacture, is, however, balanced by the nuisance arising from tar and coke, of which there is none in that made from water and oil.

The removal of the coke left in the retort (to effect which in the ordinary process it must be allowed to cool, causing loss of time) has been pro-

ductive of serious disadvantage in making coal-gas. To obviate this, a very simple and neat arrangement has been registered* which promises to be a valuable improvement, facilitating its manufacture and use on the large scale, as well as in smaller gas-making apparatus. Figure 20 is a transverse, and

Fig. 20. Fig. 21.

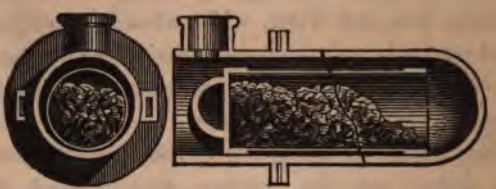
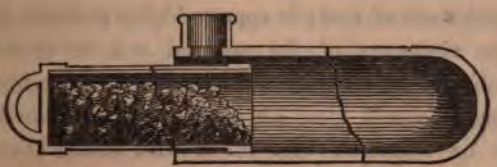


figure 21 a longitudinal section of a retort fitted with this improvement, which consists of an iron cylinder of smaller diameter than the retort, within which the coal is introduced and submitted to distillation. The gases cannot escape as they are generated from this inner moveable cylinder except at its further end, where they enter the fixed retort, through the whole length of which they have to travel back before they can escape by the pipe at the top. By this arrangement they are detained longer under the influence of the heat, and a more complete distillation attended with an increased quantity of gas is the result. By simply removing the end cover of the retort, when a charge of coal with its contents of coke has been properly distilled, the inner cylinder may be taken out, and another with a fresh charge of coal substituted

* Hall and Wilson, Manchester.

at once, without cooling the retort or otherwise losing time. Figure 22 shows the inner cylinder nearly drawn out. The smaller quantity of tar left

Fig 22.



by this plan in the condenser is continually run into the inner cylinder and re-distilled, saving much dirt, smell, and trouble. The inventors of this improvement have another, consisting of a carriage on wheels which may, if desired, be made to run on a railway from the mouth of the retort to the coke-heap—whereby the inner cylinder is conveyed with facility from the retort, and caused to turn over and discharge its contents upon the heap.

As regards the relative cost of producing any given quantity of light and heat by olefiant, water, or coal gas, little is yet known, and there is great need of complete experiment on the subject. The cost per 1,000 cubic feet of these gases is a matter much disputed; and, even if that were settled, it would be far from settling the main question. Water is by far the cheapest material of the three: but, inasmuch as its decomposition in large quantity requires a much more intense heat than the vaporization of oil or coal, for which reason the hot products must be dismissed from

the generating furnace at a much higher temperature, causing a great loss of heat; and inasmuch also as the residuary products of its decomposition have little market value compared with those of coal; it appears highly probable that the cheapness of the material will be at least balanced by the greater cost of its decomposition; and this will most likely be the case, whether it be compared with oil or with coal. That is not all;—hydrogen is the lightest of all gases, being fourteen times lighter than air, sixteen times lighter than oxygen, and *eight times lighter than carburetted hydrogen*. *Pure* hydrogen, therefore, (and some of the water gas patentees say that they do produce it in purity) is a gas of extreme tenuity, requiring a large volume of it to produce a small effect. In experiments tried by the writer on its merits as a heating gas, the rapidity with which the gas-holder sank in obtaining a moderate effect was matter of surprise; clearly demonstrating, that the price per 1000 cubic feet of any gas is a very fallacious mode of estimating its real value. The only true way of comparing the relative values of any given quantity of different gases is, to obtain, by a careful use of the photometer and thermometer, a correct measure of the light and heat produced in a given time, and of the material and fuel consumed in the production—deducting for each gas the value of the residuum (if any) left in the retort and purifier.

The power of electricity to decompose water is another long-known means of generating hydrogen gas, which was discovered by Sir A. Carlisle, who first obtained hydrogen at the negative wire of a galvanic battery. The gas thus obtained appears to differ in no respect from that generated by the decomposition of water or steam by hot iron or charcoal. But surprising accounts have recently come over from America with respect to the facility of some new mode of obtaining it by electricity, said to be invented by a Mr. Paine. American newspapers tell us that "the entire labour to make a day's supply for a dwelling does not occupy two minutes in turning a crank." "Wood, coals, oil, and fluid may be all dispensed with." These accounts, backed by the advances (greater than our own) which our transatlantic friends have made in applying the wonders of electric communication to purposes of general and public utility, has arrested the attention of all persons interested in gas; but since the foregoing was written, more recent accounts* throw such a doubtful appearance over the whole statement, that it would be premature to say more than that the marvellous results really obtained of late years through this agency encourage us to hope for more.

Among gas stoves, or other modes of heating by gas air that is to be breathed by human beings, all those in which ample and undeniable provision is not made for removing the products of com-

* See the "Patent Journal," July 20, 1850.

bustion should be carefully avoided. Some of the patentees of the water gas argue that its combustion does not vitiate air, the product being simply water. Even if this were correct, the argument would not hold good; *oxygen* combines with hydrogen to form water, and as it can only be obtained from the atmosphere of the room, which consists chiefly of nitrogen four-fifths and oxygen one-fifth, this abstraction of oxygen vitiates the air by leaving nitrogen in excess. But hydrogen cannot be obtained in such extreme purity by ordinary means, and recent experiments by Dr. Fyfe, of Aberdeen, go to prove that a large per centage of water gas consists of carbonic oxide and acid; both totally unfit for respiration. Other advocates of water gas parry this objection, by saying that a room is not a close box, and that as much ventilation may be given as will balance the vitiation; but it must be remembered that in cold weather increase of ventilation demands increase of heat, and that where the heat is supplied directly from gas combustion, increased vitiation will follow in the same proportion. For this reason no gas stove or burner ought to be used without means for keeping separate and carrying away its products.

Even though it were possible to obtain hydrogen by either of these processes in a state of absolute purity without any admixture of carbon, any neglect in the frequent replenishing of the purifier with lime would permit carbonaceous gases to pass through the burner; and as rapid vitiation would

be the inevitable result, the purity of atmosphere ought not to be left to the circumspection and care of persons having charge of gas-making apparatus, when the means of burning it in separate stoves or vessels furnished with a pipe to carry off the products of combustion are so easily applied. A mode of using gas for heating apartments, invented by a Mr. Edwards, has been lately described in that useful periodical "The Builder," entirely in accordance with this observation. It is called the *atmopyre*. It is not stated what kind of gas is used for it, but from its nature there would seem to be no objection to using the very foulest carburetted hydrogen. The gas is introduced to the under-side of a series of small clay "hoods" perforated with extremely minute holes. Here it mixes with air, forming that explosive mixture which (when ignited) proves so fatal to the miner. This mixture passing through the small orifices is ignited outside the hoods, whence ensues a continual series of very minute explosions causing a slight murmuring sound and the evolution of great heat. The small holes prevent the explosions from extending to the body of gas inside the hoods, on the same principle that finely perforated wire ensures safety in the use of the Davy lamp in mines. Twelve of these "hoods" are encased in earthenware, which becomes heated *beyond* 500° *Fahrt.* This is enclosed in another case, external air being passed into the room between the two cases; and the vitiated products are carried by a pipe from the inner case

to the chimney. With proper limitation by stop-cock to the quantity of gas admitted under each hood, so as to prevent surplus or overflow which by mixture with air would explode, there seems to be nothing objectionable in this mode of obtaining heat from gas, except the high temperature of the air-heating surface; which may probably be reduced by using fewer hoods and larger enclosures, or gas stoves of a kind affording more extensive heating surface. The arrangement of surface shown in figures 10 and 11 might be advantageously applied to this purpose.

If we consider that according to good medical authority, every individual makes on an average twenty inspirations per minute; and that at every inspiration he inhales sixteen cubic inches of air which is instantly brought in the lungs into intimate and extensive contact with his blood, making a total exceeding 1,600 gallons of air daily inhaled; we shall see that a very slight admixture (say only one part in five-hundred) of carbonic acid gas with air so breathed will amount daily to 28,800 infinitesimal doses of that deadly poison which, in a more concentrated form in the black hole of Calcutta, in one night destroyed 123 persons; which more recently, in the steerage of the Londonderry steamer, in much shorter time consigned 72 unfortunates to eternity;* and which, in its more fatal proportions of carbonic oxide, enables the suicide with closed door and windows to effect his rash

* See the "Londonderry Standard." Dec. 8th, 1848.

purpose:—and, therefore, that all chances of breathing such admixture should be carefully excluded.

The prominent and important position which gas promises to assume among our ventilating agencies, both for extracting vitiated and for warming fresh air, renders desirable a more widely spread knowledge of its manufacture and chemical constitution; and the great danger to health that results from its *injudicious* application as a means for warming air, demonstrates the necessity for its being brought under scientific restriction.

On the other hand, the great convenience with which it can be conveyed through very small pipes to inaccessible situations, and instantly controlled by a stop-cock fixed within reach (see pp. 27, 58); the avoidance of the smoke discharged from the upper ends of ventilating shafts when rarefied by coal burning within them; the advantage of performing the various duties of lighting, cooking, warming, and ventilating, by one and the same agent; the absence of dirt caused by large quantities of fuel brought into apartments; and other benefits which could be named; would render the more general introduction of gas for these purposes, *in such manner as would not be prejudicial to health*, a matter of great national utility. The day is probably not far distant in which considerable change will have taken place in these departments of domestic improvement.

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The aim of these "Hints" has so far been to

induce the planning of the measures proper for the effectual performance of ventilating appliances before buildings are constructed, and to show the difficulties which beset the operator if not thought of till afterwards. What has been stated will, therefore, apply chiefly to buildings yet to be erected, and in which, consequently, radical measures may be adopted: but, as partial and less perfect expedients, many of them liable to grave objection, but still better than nothing,—and as the best which can, in many previously constructed buildings, be adopted,—it is now intended to allude to several kinds of window-ventilators, and to show how to select from among them those which are most applicable to each particular case, so that they may be used in the least objectionable manner.

The oldest of these, probably, consists of a pane of glass (of the same size as the others of which the window consists) hinged on one side, so as to open inwards like a door. The serious in-draft of cold air through such undefended opening in cool weather, compels the constant closing of the pane, which in most cases amounts to a total suspension of that change of air which is nearly as necessary in winter as in summer.

With a view, doubtless, to remedy this defect, an immoveable tin-plate was invented, with a circular opening cut in it, within which was fitted a fan or vane made of a round plate cut radially nearly up to the centre—the leaves so formed being deflected to an angle of 45°, and revolving on a

spindle, which revolution is caused by the entrant air striking the deflected leaves or blades. This rude contrivance would be more aptly termed a "disperser" than a "ventilator." As far as it goes it impedes ventilation and light, and its sole value lies in dividing such air as can pass between the leaves into numerous spiral currents; which mitigates, while it does not prevent, their injurious effect on those who sit near them. The working parts soon wear, and a constant rattling ensues.

An improvement in this was effected by substituting a plate of perforated zinc for a pane of glass, which being a fixture is noiseless, and the perforations diminish the volume of cold draft. But it impedes light, and the perforations are necessarily so close together, that the numerous small currents unite again as soon as they have passed through the plate, with reduced, but still unpleasant effect in freezing weather.

The tendencies and evil effects of all sorts of moveable doors and openings in windows, whether closing on pivots or of the kind shown in figure 12, have been illustrated when speaking of factories (page 9) and schools (page 58.)

The next step was, to supply fresh air through windows *in divided streams*, without impeding light; which purpose was effected by narrow slips of glass arranged horizontally one above the other at an angle of 45°, sloping outwards and downwards in the manner of a louvre or Venetian blind. This performed very well till winter came, when it

became requisite to check the cold air by adopting a method of closing the slits or spaces between the glass slips to any desired degree; which rendered them defective in principle, by stopping the change of air to the same extent as it reduced the cold draft.

A better kind of window-ventilator, intended never to require closing, has been introduced and called "Lochhead's ventilating glass," in which the fresh air openings are not confined to one or two panes, but are intended to be used all along the top of the window. They are formed by narrow vertical or horizontal slits in the fixed pane, in an oblique direction outwards and downwards, each about $2\frac{1}{2}$ inches long, $\frac{1}{8}$ inch wide, and $1\frac{1}{2}$ inches apart, by which means considerable diffusion is attained, and the cold draft mitigated. Probably in winter great difference will be felt between the temperature near the fire and that near the window, and it might be found advantageous to reduce the width of the slits to $\frac{1}{16}$ inch, and apply these panes in two windows instead of one; so as to obtain, with the same area of opening, a larger ventilating surface and greater diffusion.

Another kind has been made, carrying out the idea of extensive diffusion more fully, by small circular oblique perforations $\frac{1}{16}$ or $\frac{1}{8}$ inch in diameter, and about 2 inches apart. This requires a still greater number of perforated panes, to obtain the proper quantity of fresh air; and they should be spread over

the entire upper half of each window. The extreme subdivision and distance between the perforations are meritorious features in this plan, which seems less open to objection than any of the others. But the best of these fail where shutters are used; which, being closed when the room is lighted, *stop the change of air when it is most needed.* To meet this difficulty, Sheringham's ventilator may be built into the outer wall, opposite to the fire-place, and close under the cornice. It is a flap hinged at the bottom, kept always open by a spring, and closed more or less by a cord. The air being directed upwards by it, is compelled to mix with that near the ceiling before it can descend. It is therefore a better mode of obtaining fresh air, than any of those which do not proceed on the principle of warming it before it enters. Two or three small ventilators of this kind for any room, with an interval between, are preferable to one large one.

Those which have been spoken of are all ingress ventilators: for egress openings, on a proper system, no other contrivance is required than a neat grating. Ventilation implies motion; no kind of valve can make air move; it is only useful as a regulator or director. Arnott's valve is the best known of the ventilators or valves for egress, and consists of an oblong iron frame built into an egress flue, with an iron tube of the same size as the frame fixed to the back of it, and passing through the brickwork, so as to establish a commu-

nication between the room and the flue. Within this frame an oblong plate, nearly filling the opening into the flue, is balanced with great exactness on steel pivots, or pins with fine hardened edges, fixed rather above the centre-line of the plate so as to permit it to swing on them as centres backwards and forwards with a very slight breath of air. By means of a small weight moveable horizontally to or from the plate by a screw on a rod attached to the plate, its balance is adjustable with great nicety, and in such manner that the weight keeps the plate closed against a rebate in the frame when a downward draft sets into the room from the flue, and opens it when the draft tends in the contrary direction. It has been largely used in egress openings, and if it be not inserted into a *smoke flue*, performs a useful office in preventing down drafts, but all that it can effect is to prevent a down draft, where an upward draft ought to be; if the plan of ventilation adopted be efficient, the draft will always be upwards without it, and therefore the valve is, *with good ventilation*, unnecessary. It has also been applied in chimney-breasts, to ventilate by means of their draft, but the smoky appearance visible about most valves so applied, shews that their action is not so instantaneous in preventing downward drafts as is required. After being some time in use, the working parts become worn, and an unpleasant noise ensues.

A self-acting valve for egress of vitiated air from rooms, similar in principle and purpose to

Dr. Arnott's, but of cheaper construction, has been devised by Joseph Toynbee, Esq., for the more extensive carrying out of the benevolent objects of the Samaritan fund, in rooms occupied by the very poorest classes. It consists of a plate of perforated zinc or wire-gauze, having a flap of silk hanging behind and against it; which with the silk is attached across the end of a tin, iron, or zinc tube about 6 inches square, or of the size of a brick 9 × 3 inches. This tube is built into the chimney-breast, the flap opening backwards to admit vitiated air from the room into the chimney, but closing whenever it attempts to return. The cost of this valve is so very trifling as to make it a valuable addition to our means of obtaining a change of air when the absence of more perfect arrangements within the walls, and the extreme poverty of the occupants, renders any but a nominal expense impracticable. It must be borne in mind, however, that there is nothing either in this or in Arnott's valve to *cause* a current in the right direction, their sole object being to *prevent* it from taking effect in the wrong; but there are so many rooms, especially those for the poor, constructed in such an erroneous manner as to make fundamental provision impossible, that these valves will often alleviate, even where they cannot cure. In the erection of such buildings distinct air-flues should be formed in the stack separate from the chimneys (see page 70), and if so formed in connexion with other proper constructive arrangements, no valve will be required.

On the whole, window and valve ventilation, whether intended for ingress or egress of air, (and it is often applied in both ways) is from its nature, often uncertain in its operation, and unpleasant in its effects; and therefore only to be resorted to when radical measures, forming a component part of the structure, have been altogether neglected.

A ventilator for compelling egress of vitiated air has been patented by Dr. Chowne, and has excited considerable attention from its asserted principle involving a contradiction of the known laws of pneumatics. It is called the "inverted air siphon," and consists simply of a vertical tube bent upwards at the lower end so as to form an inverted siphon having its two legs of unequal length pointing upwards. The patentee states, that "whether in the open air, or with the shorter leg communicating with a room or other place, the air circulates up the longer leg, and moves down the shorter leg," "*and no artificial heat is necessary to the longer leg to cause this action to take place.*" This action he states to be the result of "a principle which he has found to prevail in the atmosphere of moving up the longer leg of a siphon, and descending in the shorter leg;" and he further compares it to the action of an ordinary liquor siphon, but reversed in its direction by reason of its inverted position.

Hitherto *heat* has been held to be the cause of motion in air; acting on it either directly by altering the specific gravity of portions of it, thus

destroying its equilibrium, whence movements ensue in the same manner that winds are set in motion by solar heat; or indirectly through the intervention of machinery. That any inert tube bent into any conceivable shape should without heat, and solely as a consequence of such shape, impart motion to an atmosphere previously at rest, appeared to the writer so inexplicable on any known principle, that he fell into cogitations on the subject which assumed the following form:—

The comparison with an ordinary siphon will not hold good; there is no analogy between the two cases. The action of a common siphon depends entirely on the relative specific gravities of two different fluids, one of which is air, the other water or some other liquid; the latter being very much heavier than the former, which is therefore unable to sustain a column of the liquid in the longer leg. If we suppose the longer leg of the air-siphon to be *heated*, we have a somewhat parallel case, having then to deal with two different specific gravities; namely, that of air of the temperature and density which prevailed before the heating, and that of air which has been rendered specifically lighter by such heating. But this case is expressly excluded from the argument, by the foregoing extract marked in italics, and taken from the patentee's specification, which virtually assumes the air-siphon to be immersed in a homogeneous medium of uniform temperature throughout; and, therefore, all reference to the action of the ordinary siphon

fails in accounting for a movement of the air in this inverted siphon, and we are driven back upon the configuration, or bending of the end of the tube, to discover why the stated movement is produced; a question of which it affords no satisfactory solution.

Let us suppose any siphon, either of the ordinary form, or of this inverted form, similarly *immersed* in a stagnant pool or vessel of water, instead of in air. Will the water immediately begin and continue to flow through the siphon, in any determinate direction? If Dr. Chowne's principle be correct, it ought to do so; the only difference as regards the question under discussion being, that one is a liquid, the other a gaseous substance; but both are subject to the same laws of gravitation and motion, and in both, *pressure is equal in every direction.* This is precisely a parallel case with the air siphon; but will it be asserted that by the mere dipping of a bent tube in an upright position under water, the water will be made to flow continuously through it?

The principle which our investigator considers he has discovered, is certainly not referrible to any known law; and as it resolves itself into a mere question of the form of the lower end of the tube, on which its supposed action is said to depend, there seems to be no satisfactory mode of accounting for the alleged movement down the short leg, other than some effect of heat which may have escaped his observation; for it were quite contrary to science to suppose, that configuration can *cause*

*motion*, or communicate impulse to a body in a state of rest.

But the atmosphere is seldom, if ever in a state of absolute rest. Plane surfaces at right angles with the rays of the mid-day sun, will often be hotter than similar surfaces having a northern, eastern, or western aspect; and from many other causes some objects will be warmer than others, and slight disturbances of equilibrium will thence ensue even in the calmest weather, causing imperceptible undulations. So nice is the balance of atmospheric pressure, that the slightest movement, the least variation in temperature or density, causes particles of air to change their positions. The average bulk of the human body, measured by the quantity of water displaced by it when immersed, is about five cubic feet; and a person walking through air agitates a much larger volume of it than this for some time,—just as a large fish swimming rapidly through still water, or as a stone thrown into it, may be observed to cause an agitation which does not immediately subside. Though we have no right, therefore, to assume that the air is ever in a state of perfect quiescence, it still seems difficult to imagine how such slight and unfelt motions as these can produce such considerable exhaustion as is necessary to cause the effectual ventilation of a room.

If a brick chimney have the smoke of a fire passing up through it for some hours, the mass of brickwork forming its sides will imbibe heat,

which it will retain long after the fire is extinguished. The next morning, before the fire is lighted, the body of air in the house will, probably, be cooler than that in the chimney; in which case, provided there be no impediment to the draft of the chimney, an upward current will take place, it being then in the condition of a rarefied shaft, though but in a small degree; and if the lower end of the chimney be closed by a register grate, and one of these inverted siphons applied through an opening in the chimney-breast, it will doubtless act in the right direction. Some cause similar to this may possibly have led to the belief that the siphon would act well at all times and in all places; but the question still remains untouched (so far as we have gone), whether a straight pipe inserted into the chimney under similar circumstances, would not ventilate the room just as well as a siphon; for no satisfactory scientific reason has yet been adduced confirmatory of the virtue supposed to reside in the crooked end, compelling the extraction of air. It is also possible that in the inventor's trials, there may have been external causes in operation inducing an upward action, such as the action of wind or light airs in motion near the top of the long leg—such motions being likely to be caused by adjacent buildings or other local circumstances.

One of these possible sources of error is excluded from the question by the passage in the inventor's description, which affirms that this determinate

motion in a given direction will take place through the siphon "in the open air." This is a matter so easily to be tested by experiment, that further observations will presently be made upon it.

Any spontaneous action or operation which cannot clearly be shown to result infallibly from known physical laws, requires a careful investigation before credence be implicitly yielded to its due performance. The asserted action of the air-siphon appears to fall within this category, as new laws would need to be discovered to explain it. There are doubtless many such laws that have as yet escaped human cognizance, some of which may tend to induce an action in the air-siphon; but all that we can do in such case is, to reason upon those laws which we do know, and then try whether our reasonings be verified or falsified by experiment.

The only feature of the proposed air-siphon which possesses any originality of conception, is that which relates to its action independently of the effect of heat upon it. Shortly previous to the year 1681, a stove was exhibited in Paris, by M. Daslesme, consisting of a cup or vase in which the fuel was placed, the flame passing downwards through the fire into a siphon pipe, with its longer leg carried up into a chimney closed at the lower end. This stove was imitated by the celebrated Franklin, in America, in 1745, in the Pennsylvanian fireplace, and more closely in a stove, which he afterwards used for burning its own smoke, by

making it pass downwards through the ignited fuel: this last stove was almost an exact copy of Daslesme's. Eighty years afterwards, Tredgold proposed *to ventilate rooms* by an inverted siphon, whose upward or exhausting leg was to pass into a chimney. But in these adaptations, the action of the siphon was pre-supposed to be commenced by rarefaction, and maintained by the fire burning in the short leg keeping the chimney or long leg rarefied; and Tredgold's description of his siphon (p. 238 in his work) expressly requires one leg to be "so near the fire that the air in that leg will become warmer than the air in the other leg." These philosophers appear therefore to have seen that something was necessary beyond the mere configuration, to cause air to move in quantity through an inverted siphon; and the idea of its acting without such assistance possesses a novelty, the fallacy of which, however, is seen on further investigation.

Seeing that if this result could be realised, great benefits to society would ensue, and not wishing to trust entirely to theoretical doubts and objections, reasonable though they seemed, the writer resolved to put the question to the test of actual experiment. A siphon pipe of tin was made 3 inches in diameter, its short leg 12 inches long, the longer leg 15 feet long. The short leg was set up in a room to which the air had free access, and the long leg was carried up outside the building. It was provided at the lower end with two covers,

*a* and *b*, as shown in figure 23. When the cover *b* was closed, and *a* left open, the siphon was in a condition to act on Chowne's patent principle; when *a* was closed and *b* opened, it was in the condition of a simple vertical pipe. In several of the first trials, the draft indicated by the smoke of burnt paper was in the wrong direction, sometimes strongly so; showing that the capabilities of the siphon were at all events but weak, not being able to resist a slight "blow-down." It being found that the ridge was higher than the top of the long leg, it was deemed only fair to carry that leg up above the ridge, and 5 feet were therefore added, making the long leg 20 feet. This caused an amendment; but still, after numerous trials, in calm weather and windy, under different temperatures and winds, the air was found sometimes to move inwards instead of outwards, not always moving with much force in either direction. *Whenever the siphon drew well, the straight pipe drew with equal force;* when the siphon would not draw, neither did the straight pipe; and when the siphon blew downwards, the pipe did likewise.

Fig. 23.

So far the experiment had been a comparison between a *vertical* pipe and an inverted siphon, and little or no difference was found between their

respective performances. The next step was, to institute a comparison between a *horizontal* pipe and a siphon. A branch pipe 3 inches in diameter and 12 inches long, furnished with a cover, was inserted into the side of the long leg at *c*. Numerous trials proved that the horizontal pipe, as well as the vertical, was fully as effectual as the siphon for the extraction of air; close observation could trace no perceptible difference in their effect.

These trials were carried on in the centre of the city of Manchester. These are the places where good ventilation is most required, but where eddies and local currents will be most likely to interfere with its being obtained. To remove the experiments as far as possible from disturbing influences, many other trials were made in the environs of the city, where the absence of higher buildings prevented all chance of interference from local currents. These were made with a smaller and portable siphon two inches in diameter, the short leg 9 inches, the long leg 5 feet in length. (Figure 23.) A straight pipe of the same length and size was strapped to it, so that the action of both pipes might be noted under precisely similar circumstances, and at the same instant of time. This double pipe was tried under every variety of circumstance; in the open air and within doors; in numerous rooms, with doors closed, and doors opened; and in various states of weather. *In all cases the extracting powers of the straight pipe equalled those of the siphon.* In a room with doors

and other openings closed, so as to keep its air as quiescent as possible, a little of the smoke was drawn up both the pipes, but very slowly; it was found that the action of both was accelerated by blowing the breath horizontally across their upper ends; and the effect of small bellows similarly directed, was a great increase of acceleration. When the nose-pipe of the bellows was pointed obliquely upwards, there was also a similar acceleration; but when pointed obliquely downwards at an angle of about $22\frac{1}{2}$ degrees, the upward passage of smoke was immediately stopped.

The inference to be drawn from these results is, that lateral motions of air, whether playing gently or sweeping forcibly in a horizontal direction across the top of any tube or chimney, tend to excite an upward current or suction through it, *irrespective of its form at the lower end.* This cause of upward motion through an upright tube is no new theory as regards the stronger "currents of wind;" it did not escape the acute perceptions of Tredgold, who gives us a figure in illustration of it (p. 93, 3rd edition, 1836); but it does not appear to have been noticed in connexion with those more gentle movements and imperceptible (because unfelt and invisible) undulations which undoubtedly float in very calm atmospheres, and produce effects proportionate to their activity. Some such cause as these lateral currents acting with greater force high in the air it probably is, which induces in a factory chimney a generally strong upward

current, before any rarefaction has been excited within it at the bottom,—a fact which has frequently come under observation.

Another conclusion arising from these simple experiments is, that wherever an inverted siphon will operate to the extraction of air, a straight tube (whether arranged horizontally or vertically at the lower end) will act equally well; that the upward action through the long leg is induced at the upper end of that leg, and does not depend upon any shorter leg, nor upon any bent or other configuration that may be applied to its lower end; and therefore that the siphon is not the cause whereby the air is moved.

But as a ventilator, the operation of an *unrarefied pipe*, whether straight or siphoned, will be generally unsatisfactory. We have shown that its extracting powers depend on external movements of air taking effect at the top. In hot and close weather, when ventilation will be most in demand, that is precisely the time at which these movements will be least active, and therefore its operation will be then the most feeble; and the aid of heat must be invoked to communicate an upward impulse.

The only advantage to be derived from the use of an inverted siphon for ventilating purposes is in those cases where, owing to deep ornamental cornices or similar causes, an opening cannot be made in a closed-up chimney just under the ceiling. If the opening be made lower down, a lodgment of vitiated air will always remain under the ceiling

and above the openings, which when cooled will descend and mingle with the air of the room. An inverted siphon, or a bent tube, applied in an air-tight manner to this opening, and carried close under the ceiling, will dislodge such vitiated stratum, and with rapidity if the chimney be warmed. But the idea is devoid of novelty, being illustrated by Tredgold (p. 238).

This disquisition into the causes of motion in the air-siphon has extended itself to greater length than was at first intended. But as so simple a mode of extracting foul air from rooms would (had it been correct in theory and more effectual in practice than other modes) have been a national blessing, and as numerous inquiries have been made of the writer by persons interested in ventilation, the importance of the subject justifies these prolonged observations. Dr. Chowne has a claim on the thanks of the community, if it be only for the eliciting of true principles by the discussion which his supposed discovery has excited; and also on their sympathy, as a victim of those unjust and impolitic laws respecting inventions, the tendency of which is to drive ingenious men, to whose minds a philosophical conception may present itself under the seductive aspect of *a discovery*, into gigantic expenses without its undergoing needful lengthened investigation, enquiry, and experiment; which would, under the existing system, amount to such disclosure and *publication* as would effectually bar any claim for an interest in an invention.

Hollow walls are a valuable assistance to the ingress of fresh air, and its conveyance from the source of heat to the various apartments of a building. Their adoption has been strongly recommended in a valuable publication designed to improve the least expensive class of tenements ;* but practically they will be found also of the greatest assistance in buildings of very superior class. The recent repeal of the duty on bricks, which bound the maker to one unvarying size, shape, and quantity of material, has removed a formidable obstacle to the progress of sanitary reform. Walls have been usually built of the minimum thickness requisite for stability, of bricks of the legal standard size, $9 \times 4\frac{1}{2} \times 3$ inches; and in such walls, channels for the passage of air cannot be had without loss of strength, increase of thickness, or inconvenient projection. But now that the fetters of taxation which bound us to a size inconsistent with modern improvement have been knocked off, and we are left at liberty to manufacture bricks of such dimensions as public convenience and health demand, sizes and forms more in accordance with the object here inculcated will be produced by the industry and enterprise of manufacturers. Hollow walls not only facilitate ventilation, but also exclude damp, and are therefore much to be desired. They have long been used in gardens to promote the health and vigour of those trees whose fruits minister to

* "The Dwellings of the Labouring Classes." By Henry Roberts, F.S.A.—Seeley, Fleet Street.

the luxurious appetite; but by a strange inconsistency, they have been very little adopted for invigorating the human subject; at least in our day, in which, in respect of hollow walls, we are far behind the ancient Romans, who more than 2000 years ago in many of their buildings used tiles with reverted edges for lining their walls, whereby a series of vertical air-flues was obtained along each side of an apartment, communicating sometimes at their lower ends with an air-heating apparatus. Remains of these have been found in this country, as well as in Rome and Pompeii.* That old-fashioned people the Chinese are also beforehand with us in their hollow tile floors and walls conveying heat,† which are in general use on that side of the globe; and ventilation would be much improved if our architects would import this very useful custom.

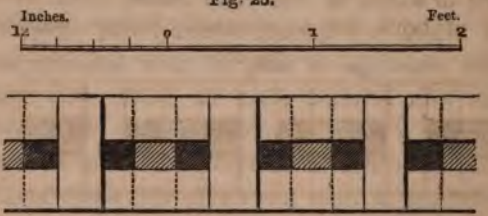
In Mr. Roberts's work three sizes of brick are illustrated as most useful for hollow walls. The twelve-inch patent bonded hollow brick (figure 24, section) is ingenious and good, but less likely to be useful for our special purpose than the others, being best suited for *horizontal* air-flues, for which it is well adapted. But *vertical* flues are much oftener required, and to obtain them the nine-inch hollow walling (figure 25, plan) made of brick $3\frac{1}{2}$ inches square, forming two

Fig. 24.

* Bernan, vol. i, pp. 48, 68, 71.
† *Ibid.*, vol., ii, p. 172.

air-spaces each $2\frac{3}{4} \times 2$ inches in every foot length of wall, is well suited; also admitting of the easy formation of horizontal air-flues where required, by

Fig. 25.




merely inserting slate 9 inches wide between two courses, by which means both the top and bottom of such flues may be formed. But these bricks will not work in with those of the common size. The eleven-inch hollow wall (figure 26, plan)

Fig. 26.

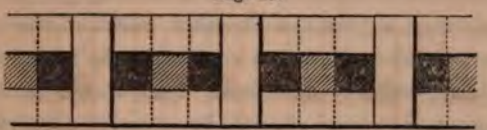
made of brick of the regular size with 2 inch-closers,* forms a thicker and stronger wall than

*An explanation of a few technical terms used by builders, will assist the general reader to understand what follows.

Those bricks which lay in the same direction as the line of wall are called *stretchers*; those crossing the wall are *headers*; small pieces inserted are *closers*. The object in arranging some bricks lengthwise and others across is to gain strength or *bond*. The rows of bricks are called *courses*. When a course consists of two stretchers and a header placed alternately (the headers of every course resting on the stretchers of the course below) the arrangement is called *Flemish bond*. When a course consists entirely of stretchers, and the course over it entirely of headers, it is called *Old English bond*. When several courses of stretchers have only one course of headers, it is called *running bond*.

that shown in figure 25, but affords less ventilation, the spaces between the headers being fewer and smaller (two of $2\frac{1}{4} \times 2$ inches to every 14 inches length of wall). The best size of brick for a nine-inch hollow wall for

Fig. 27.



ventilation appears to the author, after much consideration, to be nine inches long by three inches square. If executed in Flemish bond it will be very strong, not much more costly, and will afford two ventilating air-spaces, each three inches square to every foot length of wall; *i. e.* $\frac{1}{8}$ of a superficial foot to the foot lineal, or one foot to eight feet of wall. Deducting one-third for variations in size of bricks and casual protrusion of mortar, we have one foot of air-space to twelve feet of wall; which will not be found more than sufficient when we recollect that the air should, if possible, be introduced into a room at that side which is opposite to the fire-place; thus confining us to one only of the four sides, which will often be partially occupied by a door or window. A wall so constructed will be nearly, if not quite, as strong as an ordinary nine-inch wall; and where more strength is required it may be obtained by inserting three-inch cubes or closers in the central space between the headers in every alternate vertical series; or

(stronger still) in *every* vertical series. By this last arrangement the air-spaces will form separate flues, each three inches square, passing straight up in the centre of the wall.

These flues should be connected at their lower ends with a horizontal flue containing pipes, or conveying air from a chamber where it can be warmed, when the season requires it, by any of the modes previously described. The manner of connecting them with it will be, merely to omit the stretchers in one course of the inner face of the wall, substituting for each a three-inch closer to carry the end of the header thus left unsupported in the next course above. A horizontal series of three-inch square openings will thus be formed at any desired level, each corresponding exactly and communicating with one of the three-inch upright flues. The same mode of proceeding at the level of the skirting of any room, inserting slate nine inches wide in the joint over the openings to stop the passage of air upwards, will establish a series of openings through which air will pass into the room from behind the skirting with great diffusion.

This wall is shown (in plan, figure 27,) in juxtaposition with, and to the same scale as the two preceding, in order that comparison may be made of their relative ventilating and other properties; whence it will be seen that it affords the best ventilation with the least quantity of material, without sacrifice of stability; possessing at the same time

the great advantage of bonding easily with bricks of the common size; which will greatly facilitate the ventilation of existing buildings.

The subject of hollow walls leads naturally to that of hollow bricks and tiles; which may often be usefully applied for ventilation, especially when the course of their inner cavity is vertical. Patent bonded hollow brick (p 123) is good for horizontal flues; for upright ones those designed by Mr. Rawlinson, made of the form shown in figure 28,

Fig. 28.

$9 \times 4\frac{1}{2}$ inches, will work in well with common brick. He has also applied hollow wedge-shaped arch bricks in the large ceiling at St. George's Hall, Liverpool, whereby diffusive egress of air is ensured in a simple and easy manner. This is a revival of a good practice prevalent in past ages, as proved by many old continental buildings; in whose remains such hollow bricks may still be seen, moulded by the skill of the ancient artisan into elegant and appropriate forms.

The mode of ventilating arched ceilings hitherto practised, has frequently been to apply the hollow spaces within the spandrils to that purpose; or, where that was inconvenient, to form a flat ceiling under the arch, converting the space between the arch and the ceiling into a horizontal egress flue; openings into it through the ceiling being formed for that purpose, and one of its ends being connected with some rarefied shaft.

It has been endeavoured in this collection of "Hints" to give a brief outline of the best modes of ventilating several classes of buildings; and the necessity of having the measures proposed herein, planned and determined on before laying the foundations of the various structures has been especially inculcated, as the surest means towards a successful result, and the most economical way of obtaining it. On most of the subjects treated of, however, none but general ideas could be given, within the proposed limits; their particular application in any individual case must depend on the peculiarities of such case, as regards situation, purpose, and construction. The same general principles will apply to other kinds of buildings than those which have been especially alluded to, due regard being paid to circumstances and conditions of an ever-varying nature; respecting which, and to ensure their successful operation when applied, recourse should be had to the aid of experience.

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THE END.

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